Université Lille 1
Sciences et Technologie

Ecole Doctorale SESAM
Sciences Economiques, Sociales, de l'Aménagement et du Management

Laboratoire EQUIPPE
Laboratoire Economie Quantitative Intégration Politiques Publiques Econométrie

Thèse de doctorat en Economie (PhD in Economics)

"The Relevance of Monetary Valuations of Biodiversity For Public Decision Making"

Loraine Roy

Directeur de thèse (PhD Supervisor): Alain Ayong Le Kama

Soutenue le 3 décembre 2013 devant les membres du jury suivants:

Alain AYONG LE KAMA
(Professeur - Laboratoire EconomiX, Université Paris Ouest Nanterre La Défense)
Joachim SPANGENBERG
(Research Coordinator, Sustainable Europe Research Institute
Senior Scientist, Helmholtz Centre for Environment Research UFZ, Leipzig, Allemagne)
Jean-Michel SALLES
(Directeur de recherche CRNS – UMR LAMETA, INRA-SupAgro, Université Montpellier 1)
Bernard CHEVASSUS-AU-LOUIS
(Inspecteur général de l'agriculture - CGAAER, Paris)
Florence JANY-CATRICE
(Professeur - Laboratoire CLERSE, Université Lille 1)
François SALANIE
(Directeur de recherche INRA – UMR LERNA, Université Toulouse I)

TABLE OF CONTENTS

TABLES OF FIGURES

ACKNOWLEDGMENTS

Before all, I wish to thank warmly my PhD supervisor Alain Ayong Le Kama. He has been encouraging me since the master thesis, which I already wrote under his supervision. He supervised my work further more over the last four years, providing me way more than his scientific help. I wish for every PhD candidate to find a supervisor with so much finesse, humanity and confidence in them…but it won't be easy!

This PhD thesis has been realized at the University of Lille 1 at the EQUIPPE laboratory, and has been funded by the Regional Council of Ile-de-France (Conseil Régional Nord-Pas de Calais). It has received further financial support from my laboratory, EQUIPPE laboratory, allowing me to travel to Belpasso (Italy)[1] and to Peyresq (France)[2] to attend two exalting and fruitful Summer Schools. This gave me the opportunity to meet and debate with inspiring researchers; among them Professor John Gowdy with whom we wrote with Professor J. Barkley Rosser the article 3. Thank you, John, for this fruitful collaboration and for your trust.

Then, several professors from the Humboldt University and the Technical University of Berlin have welcomed me in their class as a visiting scholar and I thank them for that. I also want to thank the University of Austin in Texas for allowing me to access their impressive library.

When the writing was close to an end, I have benefited from stimulating and instructive feedbacks on my work from Professor J. Spangenberg who devoted a great amount of time to help me. I am extremely grateful for those comments and recommendations, and for the intellectual stimulation they provided. I have also been very lucky to get strong support for doing and finishing my PhD with serenity…and a daughter, Anna. This includes besides my PhD supervisor, my Laboratory director Hubert Jayet, my employer the University of Lille 1, the Regional Council of Ile-de-France and my family and friends.

[1] Belpasso-FEEM Summer School on "The Economics of Ecosystem Services and Biodiversity Conservation", September 2010.
[2] ALTER-Net Summer School on "Biodiversity and Ecosystem Services: An Interdisciplinary Perspective", September 2011.

In this journey, my husband took part too! His support, confidence and honesty have been precious in our stimulating discussions and more generally, our lovely life. Thank you for helping me to go on, or make fun of me when I needed it!

As for my little daughter, she did not rebel too much in the belly against the PhD, and she even learned to sleep through the nights early on! She also managed to avoid crashing my computer or vomiting on the keyboard. Her smiles have given me strengths and motivation to be even more efficient…and an ex-post Cost Benefit Analysis would definitely validate my choice of having her!

My parents are the one who saw the PhD coming, developing, finishing and who always showed me so much love and confidence in me; this has always been my big chance. My father kept reciting my PhD title and stayed alert to any information that may have been of use to me, while my mum and confidant, stood as an example of success in combining a great carrier and a loving family.

Thank you also to my grand-mother who never really understood what I was doing but kept faith in the fact that I would work one day!

Thank you to my other grand-mother who believed in me but tried to provide me with feminine literature to cool off my head!

Thank you to my grand-father who has been the first to print, read and to comment my first PhD article!

Thank you to my witty 90 years old grand-father in law who managed to ask about my progress and be genuinely interested in the subject!

Thank you to my parents in law who helped me improve my English, babysit Anna and even build scientific graphs!

Thank you also to the special baby-sitters of my daughter, starting with her Uncle Martin and the four grandparents, for whom the PhD got even more valuable for giving them some time with Anna!

Thank you to my PhD research group colleagues and friends, Alexandre, Marion, Yulia and Teresa with whom we shared visions and excitement about our researches and the wings it could give us to change the world! Claudine, I have been lucky to meet you in master and to have you since. Alexandre, thank you for giving me the opportunity to work, write and speak publicly with you; you are a brilliant mind!

Thank you also to all my friends who despite the geographical distance, kept track of my progress and believed in me. My secondary school friends have never known me out of school! Our group is very precious to me. Amélie, we will see if you get more out of my defense as I got out of yours, but sure, I'll be at least as moved to have you in my audience as I was to be in yours.

Finally, many more person should be thank here, from François to my cousins who came supporting me at my first conference. I especially want to commemorate those who are not there anymore to rejoice with me about this work and Anna, and particularly my uncle Philippe who was ready to attend my defense before I even started the PhD (he was not aware that it would be in English!), and my grand-father who would have counted among the participants actually attempting with some success to understand my defense in English!

RÉSUMÉ

La recherche portant sur l'évaluation monétaire de l'environnement est en pleine essor, en particulier dans le domaine de la biodiversité dont la dégradation apparaît comme l'un des enjeux environnementaux iconiques des années 2010. Il est souvent fait recourt à la théorie néoclassique de la valeur économique et de l'évaluation monétaire des actifs environnementaux pour estimer la valeur de la biodiversité, et ce malgré la profusion d'analyses critiques de la théorie en elle-même, mais aussi de son applicabilité à l'objet biodiversité.

On peut regrouper ces analyses critiques en trois catégories d'angle d'approche, les unes portant sur l'éthique, les secondes sur la technique et les dernières sur la pertinence des évaluations monétaires comme d'outils d'aide à la gestion et à la décision. Celles-ci permettent d'améliorer notre connaissance des différents avantages et limites, des méthodes d'évaluation monétaire existantes, mais aussi de l'appréhension-même de la biodiversité par l'approche monétaire. Ces analyses manquent encore toutefois de réflexion conceptuelle portant sur la nature de la biodiversité comme objet d'étude pour l'économie (et donc sur son statut économique), et sur les conditions d'utilisation appropriées des évaluations monétaires de la biodiversité.

Ces limites sont particulièrement problématiques dans la mesure où les évaluations monétaires sont souvent considérées comme des outils nécessaires et pertinents pour la prise de décision publique. Or, le rôle des décideurs publics est fondamental s'agissant de la biodiversité car ils ont la responsabilité d'agir pour sa préservation en influençant les comportements humains, rôle que les entités privées n'ont pas. Pour autant, la biodiversité ne peut pas être considérée comme un bien public ou une externalité, ce qui justifierait d'après la théorie néoclassique l'intervention publique. Mais celle-ci est nécessaire à la prise en compte des enjeux de long-terme et d'équité liés aux pertes de biodiversité.

Les arguments favorables au recours à l'évaluation monétaire dans le cadre de la décision publique ne manquent pas. Le plus courant d'entre eux renvoie au fait que, des utilisations humaines de la biodiversité résultent des coûts et bénéfices pour les différents agents économiques qui ne sont pas tous connus et qu'il nous faut identifier afin de pouvoir gérer la biodiversité de façon efficiente. Plusieurs auteurs rejettent toutefois cette approche et considèrent que les évaluations monétaires de la biodiversité ne sont pas nécessaires à la prise

de conscience de l'importance de la biodiversité pour les sociétés humaines et les économies humaines, et au processus de décision publique.

Ces désaccords quant aux rôles et à la pertinence des évaluations monétaires de la biodiversité sont aujourd'hui forts dans la recherche, d'autant plus qu'une branche interdisciplinaire de la recherche sur la biodiversité se développe et pousse, le courant de pensée dominant en économie à se confronter à d'autres courants de pensée économiques (écologique, comportemental, neuro-économie) et les économistes à se confronter à d'autres scientifiques (écologistes et autres experts en sciences naturelles et humaines). Il résulte de ce mouvement des incompréhensions majeures entre auteurs, mais aussi de fondamentales remises en question de la théorie et une mise en évidence de la nécessité de définir des conditions d'utilisation des méthodes d'évaluations monétaires de la biodiversité.

Cette thèse tente de ce fait d'adresser les principes fondamentaux qui régissent les évaluations monétaires du courant néoclassique, et de discuter la notion de biodiversité, dans le but d'identifier le type d'informations que les évaluations monétaires de la biodiversité peuvent et ne peuvent pas fournir, mais aussi celles qu'elles devraient et ne devraient pas fournir aux décideurs publics. Une telle analyse des évaluations monétaires conduit nécessairement à reconnaître la normativité et le manque de neutralité du courant de pensée économique dominant, et à réaliser que la biodiversité est un objet atypique d'étude qui ne peut pas être traiter comme un simple bien, une ressource naturelle ou même un actif environnemental.

Pour être plus précis avec la méthodologie adoptée dans ce travail, nous essayons tout d'abord dans l'article premier, de passer en revue les rôles que les évaluations monétaires sont censées jouer selon la littérature. Nous constatons alors que non seulement les évaluations monétaires apparaissent comme des outils d'aide à la prise de décision et à la gestion, mais qu'elle sont également censées informer, sensibiliser et convaincre, une simultanéité de rôles qui peut compromettre l'instrumentalité et neutralité supposées de ces évaluations. Nous constatons également qu'il existe deux aspects des évaluations qui sont régulièrement évoqués, soit dans un but de promotion de l'utilité des évaluations, soit dans le cadre d'une analyse critique de cette utilité. Il s'agit pour l'un d'entre eux du recours à l'unité monétaire, et pour le second de l'incorporation des évaluations dans les Analyses Coûts-Bénéfices (ACB). La littérature portant sur ces deux aspects des évaluations est large ; pour autant, nous

avons trouvé peu d'études portant sur le pouvoir d'influence de l'unité monétaire et des ACB alors même que celui-ci semble exister et semble expliquer en partie l'intensité de discordes existantes quant à la pertinence des évaluations monétaires de la biodiversité pour les décideurs publics. Nous décidons de ce fait d'explorer dans l'article premier ce que les autres sciences humaines peuvent nous apprendre à ce sujet, et concluons que l'existence d'un tel pouvoir doit être reconnu et pris en compte pour que les évaluations monétaires soient utiles et non manipulatrices.

Nous étudions ensuite le type d'approche éthique que les évaluations monétaires impliquent. Toutefois, pour ne pas restreindre notre compréhension de ce qu'est l'économie et de ce que sont les évaluations monétaires à la représentation néoclassique, nous débutons notre analyse par discuter l'approche éthique de l'économie en général en nous référant à de nombreuses définitions possibles de l'économie existantes, pour finir par déduire le risque d'un basculement conceptuel et éthique lors du recours à l'évaluation monétaire (qu'elle soit néoclassique ou pas). Nous concluons que l'économie peut être anthropocentrique (fortement ou faiblement) et instrumentale (ou purement instrumentale) et que l'approche par l'évaluation monétaire tend souvent à transformer l'approche éthique de l'économie en une approche fortement anthropocentrique et purement instrumentale. Il en résulte que le recours à l'évaluation monétaire pour estimer la valeur d'existence et d'autres valeurs de non-usage par exemple, puisse être inapproprié ou tout au moins insuffisant pour tenir compte de ces valeurs.

Une fois ces considérations relatives à la théorie économique exposée, nous nous intéressons plus particulièrement, avec deux collègues, à l'une des dimensions plus méthodologiques des évaluations monétaires, l'actualisation, et ce afin d'explorer la pertinence des évaluations monétaires à un niveau d'analyse plus restreint. Nous étudions la pertinence de la méthode traditionnelle d'actualisation (l'actualisation exponentielle) et de la méthode alternative de l'actualisation hyperbolique, pour estimer les valeurs monétaires des coûts et bénéfices environnementaux pour la société au long-terme. Grâce à une revue de littérature interdisciplinaire (économie comportementale, neuro-économie, économie de l'évolution), nous suggérons que l'actualisation hyperbolique coïncide davantage avec les comportements humains, mais aussi que cette adéquation n'est pas suffisante pour promouvoir le recours à l'actualisation hyperbolique dans les processus de décision publique. En effet, ce qui est (positif) ne doit pas nécessairement guider ce qui doit être (normatif). Nous suggérons également de voir les évaluations monétaires de la biodiversité pour la société comme des

constructions sociales, qui ne peuvent pas être résumées par la théorie des préférences individuelles. La prise de décision relative aux enjeux de biodiversité requiert des évaluations réellement sociales.

Pour finir, nous discutons dans le 4ème et dernier article de cette thèse la notion de biodiversité et le statut économique de la biodiversité, notre objectif ultime étant de confronter nos résultats avec l'approche traditionnellement adoptée en économie. Cela nous permet d'identifier les dimensions de la biodiversité que les évaluations monétaires néoclassiques semblent prendre en compte, et de réaliser que ces évaluations sont loin d'évaluer la biodiversité en tant que telle et en particulier sa dimension fonctionnelle, alors même que cette dimension est la fondation de la valeur écologique de la biodiversité. Mettre en évidence les limites des évaluations monétaires de la biodiversité nous permet d'entamer la délimitation des conditions d'utilisation de ces évaluations, et d'identifier leur domaine de pertinence pour les décideurs publics.

Ainsi, cette thèse de doctorat tente d'identifier les principaux facteurs de pertinence des évaluations monétaires pour les décideurs publics, cette pertinence dépendant de façon schématique du contenu des évaluations et de leur légitimité. Nous analysons comme premier facteur le pouvoir d'influence de l'unité monétaire et de l'ACB. Le second facteur que nous analysons correspond à l'altération possible dans l'approche éthique de l'économie qu'implique l'évaluation monétaire, rendant l'analyse fortement anthropocentrique et purement instrumentale. Le troisième facteur que nous analysons correspond au choix méthodologique de recourir à l'actualisation, tandis que le dernier facteur renvoie directement la complexité de la notion biodiversité et en particulier à la complexité de sa dimension fonctionnelle (son propre fonctionnement et sa contribution au fonctionnement de la nature). Traiter de ces facteurs conduit à utiliser et justifier une littérature et recherche interdisciplinaires portant sur la biodiversité, et un effort constant de la part des économistes de clarifier la nature de leur approche à l'objet d'étude biodiversité lorsqu'ils la valorisent monétairement.

SUMMARY

There is a profusion of research on environmental monetary valuation methods, and particularly in 'biodiversity valuations' because biodiversity losses have become one of the two environmental iconic problems of the 2010s[3]. Often, it is the neoclassical/welfare theory of the economic value and environmental asset valuation that is applied to value biodiversity. However, this theory raises many concerns, by itself, but also regarding its applicability to biodiversity.

We can schematically categorize those concerns as ethical, technical, pragmatic[4] and policy relevance concerns; and so valuations studies have focused on those concerns via empirical cases or theoretical studies, highlighting the pros and cons of different valuations methods or of the overall monetary valuation approach to biodiversity. However, there is still a lack of conceptual thinking about the nature of biodiversity as an economic object, i.e. its economic status, and about the appropriate conditions of use of monetary values.

Those gaps in knowledge are particularly problematic, once we realize that valuations are often seen as a necessary and relevant tool to made public decisions. And public decision making about biodiversity is indeed fundamental because the state is responsible for preserving biodiversity by regulating the uses humans make of it, in a way that private entities are not and cannot be. Biodiversity may not be considered a public good or an externality per se, but it is not provided by - and incorporated in - markets either, and so it does require state intervention able to take into account long-term and equity issues raised by biodiversity losses.

Many arguments and rationales exist for justifying the counsel of public decision makers with biodiversity valuations, but the most fundamental of those is that human uses of biodiversity result in some costs and some benefits for different economic agents that are not known yet, and that should be known for managing efficiently biodiversity and our impacts on it. However, many authors also argue that such valuations are not necessary to grasp the importance of biodiversity for human societies, including for human economies, and to take it into account in decision making.

[3] Zaccai (2012)

[4] Scherrer (2004), existing tools to measure and manage biodiversity do not yet satisfy simultaneously methodological, ethical, and pragmatic criteria.

Those disagreements about the role and relevance of monetary valuations in biodiversity research are strong today, and made even stronger by the fact that an interdisciplinary branch research on biodiversity is developing and confronting mainstream economists to other branches of economics (ecological, behavioral, neuro-economics), and economists to other scientists (ecology experts, natural sciences in general but also humanities). Misunderstandings, but also fundamental re-questionings of the theory result from those confrontations, and suggest the need of framing the recourse to monetary valuations of biodiversity.

This PhD tries therefore to deal with the fundamental conceptual principles of the mainstream theory of monetary valuation, and with the notion of biodiversity, in order to identify the type of information that monetary valuations of biodiversity can and cannot bring, but also should and should not attempt to bring to public decision makers. This approach requires acknowledging the normativity and lack of neutrality of the mainstream theory, and realizing that biodiversity is a particular object of study that cannot be studied as a good, or as a natural resource or even as an environmental asset.

To be more precise with the methodology of this work, we first (1st article) review the roles that monetary valuations of biodiversity are expected to play, according to the literature (pragmatic concern). We notice that actually, not only valuations are they expected to play a role of support for decision-making and management, but they are also expected to be informing, sensitizing and convincing, which may undermine the instrumental and supposedly neutral role of valuations. We also realize that two major dimensions of valuations (or valuations uses) are recurrently evoked, either for the promotion of the relevance of valuations or for the criticism of such promotion and relevance. One is the recourse to the monetary unit; the second is the use of valuations in Cost-Benefit Analysis (CBA). While a significant literature exist on monetary measures and CBA, we found few studies dealing with the influential power of money and CBA, even though it seemed to exist and explain among other things why disagreements on the relevance of valuations for public decision makers were so vivid. We therefore explore other humanities literature on this power, and conclude that it should be carefully taking into account if valuations were to be relevant but not manipulative.

We then explore the ethical approach of monetary valuations, however not by restricting ourselves to the neoclassical vision of what economics and economic values are. We rather attempt to discuss the ethical approach of economics itself (referring to numerous well-accepted definitions of biodiversity), and to deduce the ethical and conceptual shift that valuing monetarily an object, in addition to study it economically, could bring (whether the theory behind the monetary valuations was neoclassical or not). We conclude that economics is anthropocentric (strongly or weakly) and instrumental (or merely instrumental) and that the particular approach of valuing monetarily biodiversity often tended to transform the economic approach to biodiversity into a strongly anthropocentric and merely instrumental approach. This implies that the recourse to monetary valuations for valuing existence value, but also other non-use values and experience-value may be inappropriate or at least provide an incomplete picture of those values, a fact that public decision makers should be aware of.

After dealing with quite general aspects of the economic theory, we focus with John Gowdy and J. Barkley Rosser Jr.[5] on a particular technical dimension of valuations, discounting, in order to explore the relevance of valuations at a more detailed level. We study the relevance of the traditional discounting approach (the exponential utility discounting model) and of the alternative hyperbolic discounting approach, for estimating social environmental valuations. Reviewing different economic fields literature (behavioral, neuro-economics, evolutionary economics), we suggest that hyperbolic discounting is more appropriate than exponential discounting to reflect human decision making, but also that this adequacy is not sufficient to promote hyperbolic discounting for public decision making, as what is (positive) should not necessarily be the standard for what ought to be (normative). We analyze valuations as social construct and illustrate the limited informative content of the individual-preference/utility base of valuation theory for the question of how social decisions about the future, including biodiversity issues, should be made.

Finally, in the 4th and last article, we attempt to conceptualize the notion biodiversity, to discuss the biodiversity's economic status, and to ultimately confront our result with the vision that mainstream valuations of biodiversity adopt of biodiversity. This allows us to analyze which dimensions of biodiversity valuations seemed to take into account or not by valuations, and we realize that those valuations are far for valuing biodiversity per se and in particular its functional dimension, even though it is at the basis of biodiversity's ecological

[5] « The evolution of hyperbolic discounting: Implications for truly social valuation » (2013), *Journal of Economic Behavior & Organization*, 90S, pp.94–104.

value. Highlighting the limits of biodiversity valuations help us to start framing the conditions of use of valuations, and so the domain of relevance of monetary valuation of biodiversity.

To summarize, this PhD attempts to identify some major factors playing a role in the relevance of valuations for public decision makers, a relevance that schematically results from the content and the legitimacy of valuations. The first factor we deal with is the influential power of money and CBA. The second is the shift in ethical approach that monetary valuations risk to bring to the general economic approach (strongly anthropocentric and merely instrumental). The third factor is the methodological recourse to discounting and the fourth factor is the complexity of the notion biodiversity and particularly of its functional dimension (its functioning and its contribution to nature's functioning). To work on those factors, we emphasize the relevance and necessity, of an interdisciplinary research, and of a constant effort on the part of economists, to clarify the nature of their fundamental approach to biodiversity when having recourse to monetary valuations.

INTRODUCTION

1. Why human societies should be preoccupied by biodiversity losses

1.1. A recent massive concern for biodiversity losses

Today's massive political, popular and scientific concern about biodiversity degradation and depletion is more recent than other environmental concerns are like pollution, even though differences exist in the history of awareness about environmental issues between societies, for instance between Europe and the US[6]. Environmental issues cannot be separated from their "biodiversity dimension" (we will see in next section how to define biodiversity), and so issues related to biodiversity like rapid species extinction rates and deforestation are already raised before the 1980s. Actually, already in the Antiquity philosophers observed and described aspects of biodiversity degradation and human disturbance of nature, as Maris (2010) reminds us.

In the 1980s, a rise in interest in the particular "biodiversity dimension" of environmental issues is clearly noticed among scientists and portions of the public (Wilson, 1988). It is steadily picking when the National Forum on BioDiversity takes place in 1986[7], a formum aimed at warning the public and public authorities about the threat that biodiversity degradation and depletion are representing to human societies (Maris, 2010). In 1988, the United Nations Environment Programme (UNEP) explores the need for an international Convention on Biological Diversity (CBD); a convention that will be elaborated after Rio's United Nations Conference on Environment and Development in 1992 and will enter into force in 1993 with 168 signatures.

[6] The first National Park in the USA was created in 1892 while the first French National Park was created in 1964 (Maris, 2010).
[7] Forum held in Washington D.C. on September 21-24, 1986 under the auspices of the National Academy of Sciences and Smithsonian Institution (Wilson E. O., 1988).

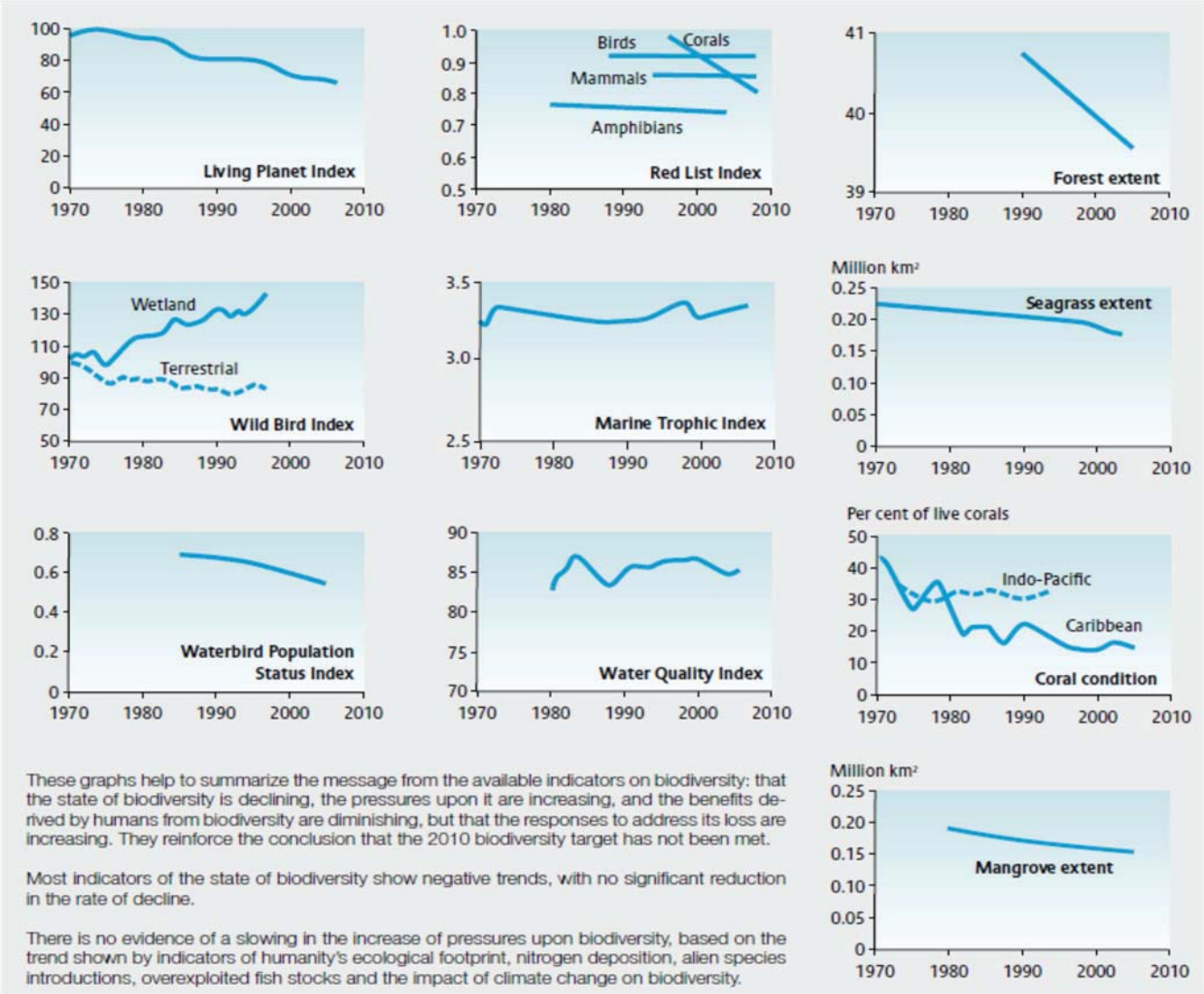
Despite this growing concern for biodiversity at the international level, biodiversity is not yet, at the end of the 1990s, systematically[8] ranked among the most prominent environmental concerns in the scientific literature and public opinion, unlike ozone depletion and climate change. For instance, the economists Sterner et al. (1998) list in the 1990s ozone depletion and especially climate change among the subjects of popular interests and academic research and publications[9]; and the sociologists Dunlap and Scare (1991) underline the influence of the "discovery" of those two issues in the 1980s, on public support for environmental protection.

In 2002 at the Johannesburg Summit (United Nations Summit on Sustainable Development), CBD's member states take more precise and constraining commitments toward the protection of biodiversity (Chevassus-au-Louis, 2010), and choose the ambitious 2010 deadline to reduce significantly biodiversity loss. This goal is missed by every member States (SCBD, 2010; Djoghlaf, 2010[10]), which leads the parties to CBD to redefine in Nagoya Summit in 2010 a new strategy and new objectives (the "Aichi Objectives") for the period 2011-2020. Biodiversity ranks from now on among the major environmental issues; Zaccai[11] (2012) even lists Climate Change and Biodiversity Loss as the two environmental iconic problems of the 2010s. In less than 30 years, a worldwide awareness of the threat that biodiversity losses represent has emerged[12].

Figure 1 provides several biodiversity indicators illustrating clear trends of biodiversity degradation over the last 40 years. Several kinds of biodiversity indicators are used because biodiversity is a multidimensional object of study, as we will see shortly. Indeed, some biodiversity indicators are dealing with species (red list index, wild bird index), others with habitats (forest extent, sea grass extent, water quality index), food webs (marine trophic index), or population (water bird population status index).

[8] Biodiversity is however more and more recognized as a pressing environmental issue, as Rischer and Markow (1998) show it in their survey of American scientists' opinion, who regard biodiversity losses as major issue, at least as prominent as global warming.
[9] In their editorial article of a special issue of the Journal *Environmental and Resource Economics* on an overview of exciting current and new research areas in environmental economics.
[10] "We have failed, individually and collectively, to fulfil the Johannesburg promise made to them by the 110 Heads of State and Government to substantially reduce the loss of biodiversity by 2010." Statement by Ahmed Djoghlaf, executive secretary of the CBD at the opening session of the tenth meeting of the conference of the parties to the CBD, Nagoya, 18 October 2010.
[11] Specialised on Environmental Management, Land Planning and Sustainable Development.
[12] Many factors have to be considered to explain why massive concerns about biodiversity degradation are so recent. The lack or limited factual life-science knowledge about the accumulated and increasing degradation of the environment is usually referred to, but Maris (2010) also underlines the role that our conceptual representation of nature has played and plays in this emergence.

Figure 1: Biodiversity Indicators



Source: SCBD, 2010

1.2. What is biodiversity and what are biodiversity losses?

The term *biodiversity* emerges at the National Forum on Biodiversity in 1986, as a contraction of the expression *biological diversity*. In its scientific acceptation, it is not redundant with notions like environment, nature or natural resources; it refers to the diversity of the living. However, in its public and political acceptations, biodiversity has become a vaguer notion (Maris, 2010), often used interchangeably with nature. For Fleury and Prévot-Juliard (2012), since Rio 1992 conference, nature has become biodiversity, and because the notion biodiversity emerges and enters into common language as a result of scientific and

public concern about biodiversity losses, it has developed an overtone: biodiversity is the threatened biological diversity (Maris, 2010), and the endangered property/dimension of nature.

To come back to its scientific acceptation, biodiversity is defined by the CBD in its article 2 as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems[13]". So biodiversity refers to the diversity of living entities existing and the diversity of environments they live in. And because living organisms interact between themselves and with their changing environment (Ehrlich and Ehrlich, 1992)[14], this leads biodiversity also to refer to the diversity of interactions and processes existing between those living entities and between those living entities and their environments.

Biodiversity can therefore be apprehended at many different levels and with many different perspectives. Maris (2010) resumes the two main perspectives existing clearly: biodiversity can be understood through a "compositionality[15]" approach and be seen as a property of nature (or more specifically a property of natural sets, i.e. the biological diversity of this set) and it can be understood through a functionalist approach and be seen as a process (referring to the diversity of flows and relationships exiting in living complexes/systems). Those visions are complementary[16], as they both ultimately see biodiversity as a property: a property of nature's composition or a property of nature's dynamics (Maris, 2010).

So biodiversity is a multidimensional object (Chevassus-au-Louis, 2009) that can be apprehended at three common levels of organization (scales) of nature: the genetic, the specific (i.e. related to species) or taxonomic and the ecosystemic (or ecologic) levels. It is however necessary to acknowledge the full ranges of levels that are necessary to study biodiversity, which – not exhaustively- include organisms, populations, species, communities,

[13] Ecosystems refer to dynamic complexes of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (SCBD, 1992).
[14] Biodiversity is the "variety of genetically distinct populations and species of plants, animals, and microorganisms with which Homo sapiens shares Earth, and the variety of ecosystems of which they are functioning parts" (Ehrlich and Ehrlich, 1992).
[15] "Compositionnaliste" in French in Maris (2010)
[16] State indicators measuring specific abundance weighted .by the biological traits (CAL, 2009) illustrate are an example of this complementarity.

ecosystems, landscapes and eco-regions (Maris, 2010, Chevassus-au-Louis, 2009). Studying and appraising biodiversity at those different levels of nature's organization can be done along numerous parameters and metrics, derived from both compositionality and functional approaches. It is not an easy task because even for notions as common as species, at least three definitions exist: the biological species, the evolution species and the ecological species (Maris, 2010)[17]. We will further introduce in section 1.4 the main biodiversity metrics existing.

We just saw that biodiversity can be seen as a property and as a process. Those two dimensions of biodiversity influence each other. Schematically, the diversity of living entities contribute to the functioning of natural systems as a whole (diverse living entities take part to a diversity of processes and functions) and those functioning systems offer habitats[18] to those entities. Ultimately, the functioning of nature allows for biodiversity-as-a-property to evolve and adapt. Therefore, those two dimensions of biodiversity are often claimed to be necessary for ensuring that nature has and maintains a capacity to function, evolve and adapt.

Many authors affirm that a positive correlation between the diversity of natural systems and the capacity of those systems to function can be found (Cardinale et al., 2006; Hooper et al., 2005 in Meinard and Grill, 2011). Amara (2010) suggests that the loss of functional diversity weaken the capacity of ecosystems to adapt, and loss of ecosystem diversity weakens the capacity of the whole biosphere to adapt. Worm et al. (2006) show that a positive correlation can also be found between the diversity of species (specific diversity) and the stability and productivity of systems (Worm et al., 2006). They suggest for example that collapse of Large Marine Ecosystem (LME) fisheries occur at a higher rate in species-poor ecosystems, and that the proportion of collapsed fisheries decay exponentially with increasing species richness[19]. Finally, losses of specific diversity are presumed to weaken the capacity of biological community to adapt (Amara, 2010) and losses of genetic diversity to weaken the capacity of species to adapt to the changes occurring in their environment (Amara, 2010; Maris, 2010) while high genetic diversity minimizes the negative effect of defective alleles (Maris, 2010).

[17] The biological species gathers inter-fecund individuals, which exclude asexual individuals. The evolution species gathers individuals from the same evolution line. The ecological species gathers individuals living the same ecological niche/adaptation zone with a distribution area hosting other individuals. (Maris, 2010, self-translated).
[18] Habitat refers to the place or type of site where an organism or population naturally occurs (CBD, 1992).
[19] "On earth as well as in the oceans, the diversity within an ecosystem does contribute to the stability and productivity within this ecosystem" (Worm et al., 2006).

However, those correlations between the diversity of the different levels of organization of biodiversity and nature's capacities (to function, to evolve, to adapt) and nature's 'health' are actually highly debated and not all straightforward and clear. Controversies exist between scientists about the correlations themselves, or about the level of biodiversity (Nunes and Van den Bergh, 2001) that contribute to nature's capacities and health.

Studying biodiversity implies therefore studying one of the fundamental dimension of nature, the diversity of its composition and its dynamics, and this requires seeing nature as a functioning system whose capacities to function *can* be impacted by biodiversity losses. It also requires recognizing biodiversity as a very complex object of study on which our knowledge is limited and uncertain.

By complex object of study, we mean that biodiversity is complicated, intricate and difficult for us to study and understand because of its intrinsic characteristics and nature. To define those characteristics and therefore what a complex object is, we rely on the systems theory and biodiversity's literature[20]. The complexity of an object/a system refers to the fact that this object/system is multidimensional - multiple scales, levels, including spatiotemporal - (Wallington et al., 2005; Ostrom, 1998; Norgaard, 2010, Limburg, 2002) that are often overlapping (Limburg, 2002), it is dynamic (Wallington et al., 2005; Scoones, 1999; (Limburg, 2002)), highly variable including in non-linear (Wegner and Pascual, 2011; Scoones, 1999; (Limburg, 2002)) and irreversible ways (Wegner and Pascual, 2011; Farley, 2008), it is interconnected (Wegner and Pascual, 2011) and interdependent (Scoones, 1999) (or multitied (Ostrom, 1998)). So it is complex because of the multiplicity of its dimensions, components, processes, and interactions of those components and processes within the system and with other systems (Limburg, 2002). And this complexity of diverse natural systems make us unable to fully predict (Wallington et al., 2005) the object/system's dynamics and its becoming, as we can only partially identify the drivers of its dynamics and non-exhaustively identify its components and interrelations.

By uncertain knowledge, we mean that we lack knowledge; we don't know with certainty the state of biodiversity and cannot predict with certainty its future evolution. This is a vague

[20] We do so even though biodiversity is not an object per se but actually a property of the object nature.

understanding of the notion uncertainty that covers situations from minor lack of knowledge to total ignorance, because we address here biodiversity and biodiversity loss in general and not in particular and concrete cases. Those different levels of uncertainty exist however, and should be identified in practice and transmitted to decision makers (as the IPCC does it for instance in its reports). They should also to be identified in order to decide the relevance of using particular evaluation tool or technique.

Hansson (2002) identifies four levels of uncertainty that decision makers can have regarding the consequences of the potential actions they could take, that can enlighten us a little more about the nature of uncertainty and especially decision making under uncertainty. Those levels are determined by the kind of knowledge we have about three things: events, outcomes and probabilities, i.e. about the events that could happen, about the outcomes that could result from those events, and about the probabilities that those events happen. At the level 1 of uncertainty, decision makers know the options they have, their impacts and their probabilities, at the level 2 of uncertainty, decision makers know the options they have and their impacts but they don't know all their probabilities, in the level 3 they still know the options they have and their impacts but none of the probabilities (except that they are different from zero) and the in the level 4 they no neither the options and impacts nor their probabilities of happening[21]. All those state of knowledge seem to be plausible for biodiversity scientists (they may be at level 4 of uncertainty for dealing with tipping points), which leads us to maintain a vague use of the notion uncertainty in this work.

Now, what are biodiversity losses? They are impoverishments of the diversity of the living occurring at all the relevant levels we mentioned, and their consequences on the environment, in which we include human societies. Those losses occur at the genetic level[22] (intra- and inter-species), at the specific level (extinction of species or diminution of their population), at the ecosystemic level[23] (perturbation or disappearance of the functions carried out by ecosystems and of the interactions between their components) and other levels like species populations, and impoverishments of the capacities of nature's system and components to evolve, adapt, and function. For instance, biodiversity losses resulting from

[21] Ignorance refers in the theory of decision to the highest levels of uncertainty (Hansson, 2002).
[22] "Genetic diversity is being lost in natural ecosystems and in systems of crop and livestock production. An example of the reduction in crop diversity can be found in China, where the number of local rice varieties being cultivated has declined from 46,000 in the 1950s to slightly more than 1,000 in 2006" (SCBD, 2010).
[23] "Ecosystems across the planet, including some with exceptionally high levels of biodiversity, have become severely fragmented, threatening the long-term viability of many species" (SCBD, 2010).

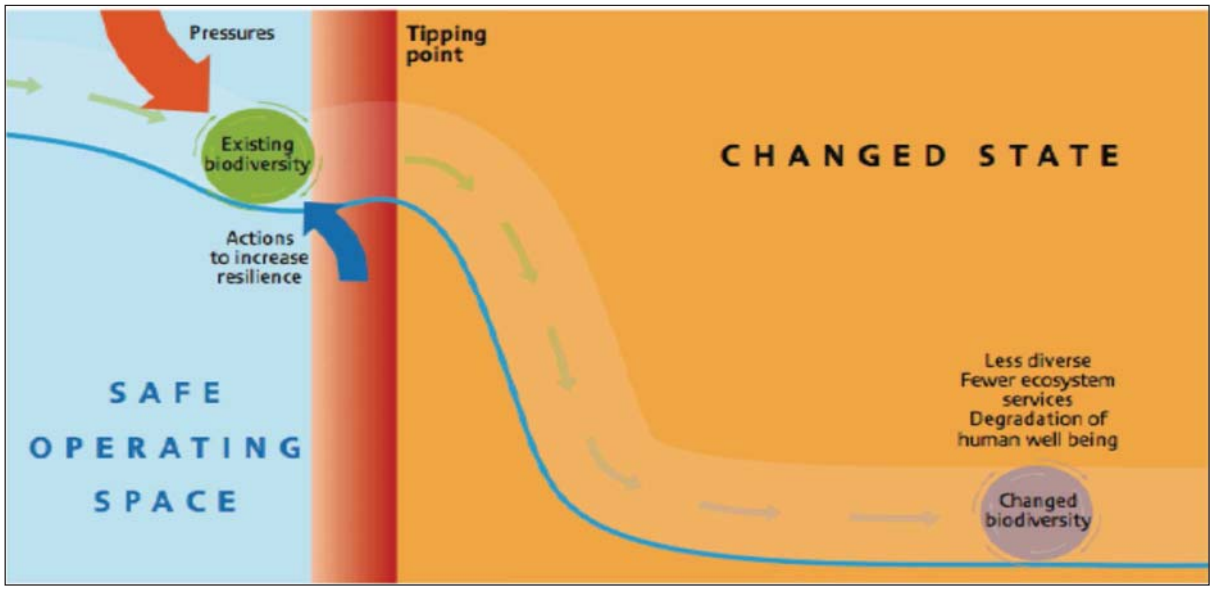
fishing have to do with fish populations being fished (age and size composition for instance), but also with the genetic structure of fishes, with by-catch species, with the trophic nets and communities and with marine habitats (Amara, 2010).

New species, interactions, and functions appear and other disappears as a result of "natural" processes and events like climate change, but also as a result of human disturbance of the ecosystems. What we observe today is an unprecedented erosion of biodiversity due to human activities (Heywood and Watson, 1995; Wilson, 2002 in Meinard and Grill, 2011). The symptomatic species extinction rates (or population declines) for instance, inform us that those human disturbances are too high[24]. *"Species in all groups with known trends are, on average, being driven closer to extinction, with amphibians facing the greatest risk and warm water reef-building corals showing the most rapid deterioration in status. Among selected vertebrate, invertebrate and plant groups, between 12% and 55% of species are currently threatened with extinction. (…) Preliminary assessments suggest that 23% of plant species are threatened" (SCBD, 2010)*[25]. They could be premonitory of a 6th extinction[26], except that unlike the previous five species extinctions, this 6th extinction would result from human activities. Indeed, Current extinction rates are estimated to be much higher than those occurring before the arrival of man (Wilson, 1988 in Weesie and Van Andel, 2003).

At worst, those unprecedented biodiversity losses we already testimony can accumulate and ultimately drastically perturb ecological systems and run dry the resilience capacity of the ecosystems. Indeed, ecological systems can be resilient until external pressures are too high (SCBD; 2010) and ecological regime shifts happened (at the tipping point, Lenton et al. (2008)) from an initial state of existing biodiversity to a change state of biodiversity. The new changed state of biodiversity is characterized by degraded state and impoverished biodiversity (see figure 1).

[24] We are looking at an acceleration rate of extinction, of the order of the fifth extinction crisis (May, 2010).
[25] A species or sub- species of plant or animal is endangered if it is sufficiently close to extinction to make its survival questionable beyond the next few years or decades. (Bishop, 1978)
[26] End-Permian, end-Cretaceous (Singh, 2002)

Figure 2. Tipping point: an illustration of the concept

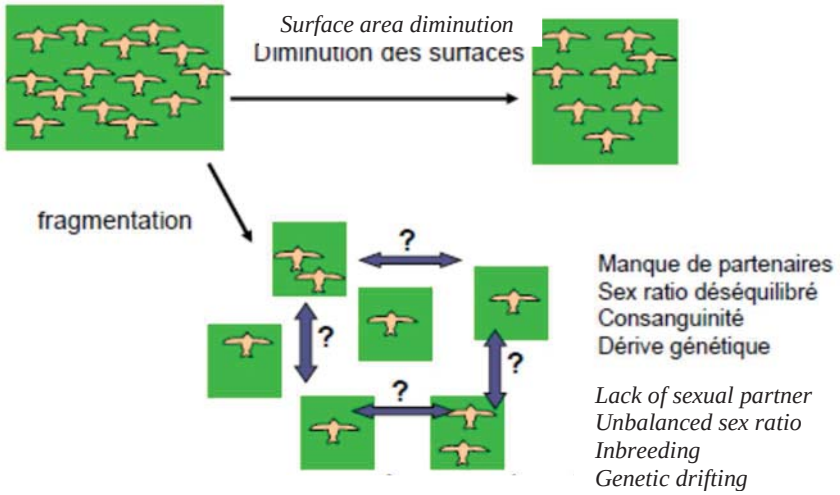


Source: Secretariat of the Convention on Biological Diversity (SCBD)

1.3. Reasons, causes, and consequences for human societies of biodiversity losses

The general causes for biodiversity losses are Habitat destruction and fragmentation, Invasive species, over-Population, Pollution, and Overexploitation of environmental resources (HIPPO). In the case of the Channel and the North Sea for instance, all those causes apply and interact (Amara, 2010). Extraction of granulate destroy spawning grounds (H), invasive species compete with native species and bring parasites (I), high density of human population (P) near the coast result in chemical pollution of the water, eutrophication and the release of macro-wastes (P), and fisheries overexploit resources, including by fishing juveniles and by-catch (O) (Amara, 2010). Obviously, human activities are highly responsible for those losses.

Figure 3. Habitat destruction and fragmentation

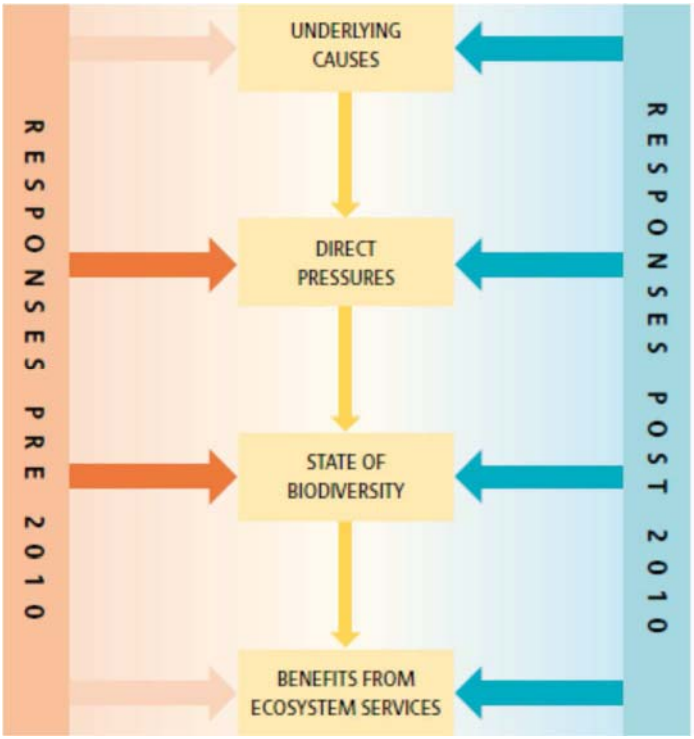


Source: Nina Hautekèete (2008), Lecture on Biodiversity Conservation, Lille 1 University

If we adopt Bromley (2006)'s approach, the cause of some outcome is understood as the mechanical cause in play in the cause-and-effect relationship, whereas the reason of the same outcome is understood as the epistemic grounds of the cause leading to the outcome. We have to consider not only mechanical causes but also final/ultimate causes, i.e. the reasons. In 2010, the SCBD confirmed this if we are to reduce biodiversity losses, and it emphasized the urgency to look at the whole causal chain of biodiversity loss. It suggested that 2010 Biodiversity Target had not been met by the parties to the Convention, first because the reasons (called "deep-rooted underlying causes to direct pressures" in the report[27]) had not been addressed in a meaningful manner (SCBD, 2010) (the first step the causal chain). The SCBD therefore suggest adopting a post-2010 approach that does look at those underlying causes and reasons. It also suggested that the failure of 2010 Targets was a result of the fact that actions aimed at protecting biodiversity had not been directed enough to ensuring that human societies continue to receive the benefits from ecosystem services over the long term (the last step of the cause chain). This is why the post-2010 perspective also emphasizes the need to look at the benefits received by humans from Ecosystem Services (we will introduce shortly this notion). However, we need to mention here that there is a risk to focus on one of those two aspects (reasons or benefits) at the expense of the other. Especially in the case of ES, Norgaard (2010) warns us against the enthusiasm that ES approach raises and that could prevent us from actually looking at the direct drivers of changes to the ecosystems.

[27] By reference to the analytical frameworks such as the PSR (Pressure, State, Response) and the DPSIR (Driving forces, Pressures, States, Impacts, Responses).

Figure 4: A change in perspective after 2010



Source: SCBD, 2010

Identifying causal chains regarding biodiversity functioning and losses (natural sciences), and regarding the relations between human societies and biodiversity (humanities sciences, among them economics) is extremely complex, because biodiversity and societies are two complex functioning systems. Some authors speak about the unpredictability of socio-ecological systems (Limburg et al., 2002 in Barnaud et al., 2011). We will see through this PhD that complexity and lack of knowledge are two key challenges to the study of biodiversity, and so to the monetary valuation of biodiversity, and that the economic literature on complexity and uncertainty is particularly relevant for dealing with biodiversity, as well as the current trend of research to develop inter- or trans-disciplinary research. So at this stage, we will only at this stage evoke simple causal chain and some of the main reasons, causes and consequences of biodiversity losses.

SBCD (2010) enumerates briefly some of the reasons of biodiversity losses: demographic change, economic activity, levels of international trade, per capita consumption patterns linked to individual wealth, cultural and religious factors; and scientific and

technological changes. It also provides some quick examples of causal chain integrating them, such as the following: the population increases at the same time that per capita consumption, demand for energy, food and water also increase, and the increase of those four demands contributes to direct pressures on biodiversity such as habitat conversion, over-exploitation of resources, nutrient pollution and climate change.

Regarding the consequences of biodiversity losses, ecology experts and biologists warn us about that they represent for nature and human societies, with arguments that are far from resulting only from their emotional attachment to nature and their environmental ethics. As we suggested already, tipping points exist (see figure 1). Small changes in biodiversity can lead to dramatic irreversible alterations in the system's ability to function and ultimately to major disturbance in human societies' functioning, because irreversible impacts on biodiversity might drastically modify the goods and services biodiversity provide (MEA, 2005; Bishop, 1978; SCBD, 2010). Table 2 provides an illustration of the socio-economic consequences of an ecological tipping point.

Figure 5. Socio-economic consequences of an ecological tipping point: the case of Newfoundland cod's stock decline

In 1990s, cod populations in NewFoundland collapsed and never recovered. According to Schrank (2005), the collapse in cod's stocks followed by a moratorium on cod fisheries in 1992 and a moratorium of other groundfish stocks led to the largest mass layoff in the history of Canada. Many fishermen faced the loss of traditional livelihoods, and in an area with few alternative resources; the adaptation to new catches industries supported fewer people than the former cod fishery (Hamilton et al, 2004). The population of Newfoundland dropped by 10% in a decade because of shrinking birth rates and substantial outmigration, and a series of government financial help (aimed at unemployed fishermen and fish plan workers) until 1998 cost government in the order of $3 billions (Schrank, 2005). Although once again rich, today's fisheries are more concentrated, requiring more capital and less labour than their predecessors. The changes make fisheries less broadly supportive of outport society (coastal community of Newfoundland) as a whole. Declining population due to reduced family size and increased outmigration, especially among young people with education and skills, is one unsurprising though unfortunate result (Hamilton and Butler, 2001).

We actually do not even have to consider biodiversity losses crisis to realize the importance of biodiversity for human societies. Human beings highly depend on some provisions like food and medications (Heal, 2004) and "naturally occurring ecosystems" (CEQ, 1993) make their provisioning system possible. For instance, the availability of varied plants and other natural compounds are indeed crucial to medicine, in developing countries where about 80% of the population relies on traditional medicine mainly derived from herbal plants (WHO, 2008 in TEEB, 2010b[28]) and in developed countries where 50% of modern pharmaceuticals are derived from or based on natural compounds (MEA, 2005). The following table on marine and coastal ecosystems illustrates how the degradation of some ecosystems can impact the way of living of human societies. It describes some forecast about the way those ecosystems will evolve until 2100 and the expected impacts of those evolutions on human societies.

Figure 6: Impacts of changes in marine and coastal ecosystems for people

Marine and coastal ecosystems to 2100

Current path:	*Impacts for people:*
Demand for seafood continues to grow as population increases and more people have sufficient income to include it in their diet. Wild fish stocks continue to come under pressure, and aquaculture expands. Progressively fishing down the marine food web comes at the expense of marine biodiversity (continuing decline in marine trophic index in many marine areas). Climate change causes fish populations to redistribute towards the poles, and tropical oceans become comparatively less diverse. Sea level rise threatens many coastal ecosystems. Ocean acidification weakens the ability of shellfish, corals and marine phytoplankton to form their skeletons, threatening to undermine marine food webs as well as reef structure. Increasing nutrient loads and pollution increase the incidence of coastal dead zones, and increased globalization creates more damage from alien invasive species transported in ship ballast water.	The decline of fish stocks and their redistribution towards the poles has major implications for food security and nutrition in poor tropical regions, as communities often rely on fish protein to supplement their diet. The impact of sea level rise, by reducing the area of coastal ecosystems, will increase hazards to human settlements, and the degradation of coastal ecosystems and coral reefs will have very negative impacts on the tourism industry.

Source: SCBD, 2010

Among the multiple approaches existing to the consequences of biodiversity losses on human societies, a quickly developing approach is the so-called Ecosystem Services (ES) approach, which can be useful here to further illustrate human society's dependence on a well-

[28] WHO - World Health Organization (2008) 'Traditional medicine'. Fact sheet 134. URL: www.who.int/mediacentre/factsheets/fs134/en.

functioning biodiversity. ES, according to TEEB (2010), are “the direct and indirect contributions of ecosystems to human wellbeing”. Those services are understood as benefits derived by human from nature, and refer in usual economic terms to goods and services. They include food and water, energy and raw resources, regulating and supporting ecosystem services that help maintain the resilience of ecosystems and biodiversity, and many other sources of benefits for recreation, mental and physical health, economic activities (fisheries, tourism), inspiration, spirituality, culture and sense of place (TEEB, 2010b). The main categories of services under this approach are the supporting services (like nutrient cycling), the provisioning services (like food), the regulating services (like climate regulation) and the cultural services (like the aesthetic aspects of biodiversity) (TEEB, 2010b). We can already mention here that it does not avoid the pre-quoted problems of dealing with complexity and knowledge gaps or of identifying causal chains, almost on the contrary. Moreover, for Norgaard (2010), the ES approach has become a paradigm for thinking about development and environment that may lead to neglect other approaches to the ecosystems and that may blinds us to the complexity of natural systems.

1.4. About biodiversity metrics

We can deduce from what precedes that the quantitative estimation of the specific diversity (diversity of species) of nature is neither simple nor an exhaustive representation of biodiversity. We saw that they are many levels of organization of nature, among them the three main genetic, specific and ecosystemic levels, and potentially many ways to apprehend the diversity of those levels including static or more functional ways. Actually, Chevassus-au-Louis (2009) suggests that it is impossible to build a unique biodiversity indicator that could provide such exhaustive representation of biodiversity.

Before all, three points need to be made. First, the notion diversity has no precise and unique meaning in mathematical terms, which implies that there are numerous ways of building biodiversity metrics (Chevassus-au-Louis, 2009). Then, and so, each biodiversity metrics relies on some interpretations of what diversity means, and relies therefore on some fundamental properties and axioms (Aulong et al., 2006). Finally, biodiversity metrics can focuses on one or several dimension(s) of biodiversity. We will mainly focus here on the

specific and the genetic diversities, and only mention that the UNEP identifies 94 categories of ecosystems.

The genetic diversity refers to the diversity of genotypes (i.e. the diversity of non-identical versions of alleles) existing within a species[29], while the specific diversity refers to the diversity of species within a site or a habitat. Measuring the diversity of a set requires counting (with a scale), comparing (with a differentiation criteria and degree) and weight (with a criteria (Maris, 2010)) and ideally, measuring biological diversity is a process that should be able to 1) differentiate the 'biological entities' (alleles or species)[30] present in the species or the site, 2) count the non-identical entities or the distance separating those entities, and 3) estimate the relative abundance[31] of entities[32] (Chevassus-au-Louis, 2009).

There are several criteria (1) that could be used to define the *distance* between biological entities (or to weight the importance/role of those entities) and they cannot all be combined. In the case of the specific diversity, we can use the phylogenetic[33] (or evolution related (Maris, 2010)) distance, the ecological (or functional) distance, the taxonomic and/or on the genetic (biological) distance to differentiate entities and categorize them.

Aulong et al. (2006) illustrate how those ideal characteristics of biodiversity indicators are hard to combine in practice. They show for instance that choosing the taxonomic criteria for distinguishing entities[34] and then counting 2) the number of species present in a site, i.e. the *richness* in species of the site, may prevent us from taking into account aspects of the diversity of the site: the differentiated contribution of each species to the overall diversity of the site resulting from their abundance and functioning role in the ecosystems, or the different

[29] Schematically, the genetic diversity results from modifications of the genomes of individuals belonging to the species. Those modifications can affect "coding" genes or "neutral" genes. In the first case, the added diversity is observable (for instance, the color of the eyes) while in the second case it is not; they can be called the phenotypic diversity (observable) and the neutral diversity (Hautekèete, 2006).
[30] Terminology from Chevassus-au-Louis (2009)
[31] The relative abundance of one species in a site hosting several species is obtained by dividing the number of entities of one species over the total number of entities of all species present in the site.
[32] Besides the distance, the richness and the relative abundance, biodiversity indicators in the case of the specific diversity should ideally, be able to take into account the spatial distribution of the species of a site, and more precisely the uniformity of their distribution and the spatial organizational pattern of those species (Chevassus-au-Louis, 2009).
[33] The phylogenetic distance estimates the proximity of two entities by analyzing the characteristics (from molecular to morphologic) they both inherited from a common ancestor.
[34] By using the "dichotomous similarity" principle (Pattanaik and Xu, 2000a and 2000b in Aulong et al., 2006) (i.e. an entity either belongs to species x or does not).

genetic diversity of the species that would attribute same diversity index to a cheetahs and to a protozoan.

Aulong et al. (2006) also introduce the well-known Shannon-Wiener and Simpson Indexes along with Berger-Parker Index, and show that while they take the richness and the abundance of species within a site into account (the abundance provides some information about the functional role of species), they do not take into account the dissimilitude between species. This dimension is dealt by axiomatic researches from Weitzman (1992, 1998) among other authors, who have developed methods to estimate aggregated dissimilitude between species using phylogenetic distances. But in those researches, it is the relative abundance of species that is absent.

Thus, numerous authors among them Chevassus-au-Louis (2009) and Aulong et al. (2006) reveal the need for multiple biodiversity metrics. Aulong et al. (2006) emphasize the need for exhaustive descriptions of the proprieties and axiomatic characteristics of biodiversity metrics, as each may take different aspects of biodiversity into account and bear different consequences. Chevassus-au-Louis (2009) concludes that biodiversity metrics need to be adapted to the ecological and institutional contexts they are being undertaken in, and to clear goals of conservation/actions. For instance, if we attempt to prevent biodiversity losses for instance, Chevassus-au-Louis (2009) suggests to use abundance measures rather than specific richness measures, because the latter requires numerous, exhaustive and precise data that we actually cannot develop and that would provide less insight into the evolution in the short term of biodiversity losses than abundance measures.

2. The theoretical foundations of monetary valuations of the environment

2.1. Monetary valuations as a particular kind of economic evaluations

Before all, what do evaluations refer to? The general understanding of the verb *to evaluate* is to determine, to set, to estimate, to appraise, to assess, to judge, to diagnostic, to identify, to define with precision the value, the significance, the importance and the limits, the

interest, the quality or the amount of something. All these verbs and nouns provide an idea of the diversity of approaches that are represented by the term *to evaluate* and that result in evaluations, but they also all refer to the activity of observing and analyzing an object in order to develop an (improved) understanding of it. To evaluate something is indeed to adopt a particular method of observation and estimation of an object (the choice of this object being part of the evaluation process) and to put in words and/or numbers this representation of it. It unavoidably implies a selection of the characteristics to be evaluated, resulting either from a value judgment about the characteristics that worth to be studied (which implies that to some extent, they are representative of the whole object studied) or from a particular interest that the evaluator can have in one of its characteristics (without this characteristic being representative of the whole object). Obviously, the same object can be evaluated differently depending on, the scientific field studying it, its epistemological and methodological choices, and the representation of the reality that the evaluator has.

What are economic evaluations then? We saw that evaluations are measurements, estimations or appraisals of qualitative and quantitative characteristics of something. What makes an evaluation being economic depends on the conception of economics we have and on the particular approach to human societies it implies. Article 2 deduces from reviewing multiple well-accepted definitions of economics that it is a science that focuses on humans and their behaviors and actions, as individuals or groups of individuals, within or without some organizations and institutions such as businesses and government. Economics can either be defined as a subject-matter science (it deals with scarce resources, ends and means, preferences…) or a type-of-approach science (efficient approach, maximizing approach…). Our choice would be to adopt Bromley's (2006) definition of economics, who suggests that the overall human behaviors and actions of interest for economics be humans' organization for their provisioning. However, we will try to avoid as much as possible to commit to any particular definition of economics in this work, and rather discuss which restrictions the particular neoclassical branch of economics brings to the economic approach. So what we actually choose to do in this work is to discuss what economics, the economic approach and economic evaluations can theoretically be, independently from any particular doctrines, to then confront our results with the restrictive neoclassical visions of those. This is why this section is rather generalist while the next section introduces the neoclassical doctrine on the economic value and monetary valuations.

The current literature on the economic evaluation may use the terms evaluation and valuation interchangeably. As Pearce et al. (2006)[35] puts it, the terminology about economic evaluations can be vague and the literature lack precision; costs can refer to different notions, and particular valuation methods can have different appellations (Hardelin et al., 2010)[36]. Closely related disciplines working on the evaluation of biodiversity moreover, may have different definitions for similar notions; option value in finance corresponds for instance to the quasi-option value in economics, and not the economical option-value (Pearce and al., 2006). Going back to the general definitions of evaluations/to evaluate and valuations/to value[37] make us realize that evaluations and valuations can be used interchangeably in the everyday language for some areas (we evaluate or value a property); but that evaluations/to evaluate cover more fields than valuations/to value do (we evaluate damages, property, effectiveness, reasons, performance, somebody's work, while we value mainly goods like a property, a painting and services). Valuations focus on value, while analysis and evaluations do not and can also deal with physical data. To some extent, evaluations correspond to appraisals, estimations, determinations of scientific nature, either because there is a scientific methodology behind, or because the evaluator has enough of a scientific legitimacy. Valuations on the other hand, do not necessarily imply a scientific procedure; they can designate the very action of valuing, of attaching an importance to something, which individuals do subjectively and without methodology.

In the scientific sphere, those subjective valuations can matter as the basis of more elaborated valuations of goods. In the neoclassical theory of value, as we will see soon, the economic value is derived from individual's utilities and preferences. They are quantified and used by economists who do valuations studies. Therefore, academic evaluations and valuations both are scientific processes and results, and economic valuations are a form of economic evaluations devoted to the measure of the economic value. However, this scientific process of quantification almost always associates the economic value to the monetary value (Champ et

[35] "Unfortunately, in much of the literature the term 'cost' appears without any qualification and the reader is sometimes left guessing whether what is being referred to, is damage, a benefit or some other cost." (OCDE, 2006).
[36] The Production Function method is also called the Change in Productivity method; the Choice Experiment method is also called the Conjoint Analysis or the Multi-Attributes Choices method (Hardelin et al., 2010).
[37] Webster's universal college dictionary (1997), Le Robert et Colins (2006), Larousse Lexis de la langue française (2002).

al., 2003)[38]. This makes the term valuations become in the literature, not only a quantitative appraisal of values, but a monetary evaluation of value. From now on, we will use the term monetary valuations of biodiversity to designate the monetary evaluations of the value of biodiversity[39], and therefore make the distinction not only between evaluations (which can measure many economic dimensions besides values, with many different units) and valuations (which focus on value), but also between monetary valuations and non-monetary valuations (which focus on value but necessarily by measuring it monetarily).

Finally, we can distinguish monetary valuations from other concepts such as analysis, indicator or index. The analysis of an object or of a situation is a process during which a particular method of thinking and interpretation is used to make sense of the situation or of the object being studied. The evaluation of an object or a situation is also a process that requires some thinking and interpreting but it ultimately focuses on – and results in - estimating (or some aspects of) the object or the situation, getting the measure (qualitative or quantitative) of it. Both analysis and evaluation are required for studying a phenomenon thanks to an analytical process. Economics' vocabulary provides us with numerous examples like the Cost-Benefit Analysis (CBA) or the Multi-Criteria Analysis (MCA), which are analytical processes combining analysis and evaluation.

Then, indicators are data that either provide raw data/information or elaborated information about a phenomenon (OECD, 1993), and that can be qualitative or quantitative. As we saw, the term evaluation designs the process of evaluating and the result of this process. On the contrary, the indicator only refers to the result of the process of evaluating; it can therefore be seen as an evaluation only if what is meant is the evaluation-as-a-result. Indicators have the property, as particular kinds of evaluations, to be already useable as tool or instrument. They are more than mere data; they provide some meaningful indication about a situation. To illustrate this with an example proper to biodiversity, we can refer to bio-indicators. The bio-indicator concept designs a species who reveal by its presence in an ecosystem that this ecosystem is healthy enough to sustain it. As any evaluations, they are "partial reflections of reality" (Meadows, 1998) as they focus on one aspect of this reality and adopt a single approach to describe it. They can be and can be aggregated (like the GDP) or not. To some

[38] "Although 'valuation' in economics commonly refers to measurements of monetary values, valuation also refers to ordering preferences among goods and attributes, whether in terms of a simple ranking or an interval scale." (Champ et al., 2003).

[39] A suggestion for allowing this distinction to be made in French is to replace Pearce et al. (2006) translation of valuation techniques *techniques d'évaluation* by *techniques de valorisation monétaire*.

extent, indexes can be seen as indicators as they are numbers or formula (resulting to a number) expressing a property or ratio (index of growth, or in figure 1 Living Planet Index).

2.2. Neoclassical theory of the valuation of environmental assets valuation

This PhD will concentrate on the essence of monetary valuations and on the particular approach that neoclassical economic adopt of monetary valuations methods. However, it must be mentioned that other valuations methods exist and can provide monetary and/or non-monetary valuations. Deliberative and group valuations methods for instance can provide both monetary and non-monetary valuations, and biophysical approaches can provide non-monetary valuations using energy or material flows as unit (TEEB, 2010).

We will introduce here some basic principles of the neoclassical theory of economic value and of environmental monetary valuation, in a seemingly non critical fashion, for the reason that the essays of the PhD themselves attempt to provide those critical analyses. Therefore, we will only mention some of the criticisms to come later without major developments.

2.2.1. Individual utility at the basis of the economic value

Environmental assets can be seen as natural providers of flows of several goods and services consumed by individuals (Bonnieux and Desaigues, 1998). Their value can be estimated by the net present value of those flows (capital asset pricing method[40]), i.e. by their market price net of the cost of bringing that service to market (Farber et al., 2002) now and in the future. However, environmental assets and some of the goods and services they provide are often public good with no market prices, or with distorted prices. Moreover, even if they had prices, “the price of a good does not reflect its importance in any overall social or philosophical sense” (Heal, 2000), as it provides a market exchange value resulting from the confrontation of individuals’ demand and supply, and so reflect a particular situation of scarcity. While the demand function can be influenced by the social and philosophical importance that individuals attach to particular goods, it is not as much this importance that is

[40] The value of a resource stock can be expressed as the Net Present Value (NPV) of the stream of service flows it is expected to yield over the lifetime of the resource (Markandya et al., 1999)

revealed by prices than the particular state of scarcity[41]. Prices are also dependent on present conditions. So while market prices stand as an available monetary proxy, economists have developed methods to approach and if possible estimate the importance and the economic value of biodiversity monetarily without relying exclusively or even partially on prices.

In neoclassical economics, it is assumed that the economic importance bestowed to goods by individuals can be estimated by a monetary value, and that it should be estimated by the monetary value of the utility/welfare/well-being that individuals derive from the good. While those three notions (utility, welfare and well-being) are different, the modern utility-based approach to value tends to have a "loose usage" (Sen, 1998) of the notion utility, and to use the three notions interchangeably when there is no public good or externalities in the Utility Function. So, in neoclassical economics, something has economic value for an individual if it provides utility to this individual. The economic value is not a component of utility but it is revealed by the observation of individuals' utility (we see however in article 4 that utility may often be handled as a source of value rather than an evidence of value). It is assumed that individuals are the best judges of the utility they derive from goods and services (Bonnieux and Desaigues, 1998; Brekke, 1997). It is also assumed that individuals derive utility from the satisfaction of their subjective preferences. So, neoclassical economists estimate the economic value of objects, by asking about individuals' preferences, or revealing the preferences of individuals via the examination of their behavior. This supposes that individuals are at all-time maximizing their utility when they make decisions, and that the observation of those decisions (or the questioning about the decisions they would make) actually reveal their preferences. Both are however strong and restrictive hypothesis as we shall see.

Utility, in neoclassical economics, is conceived not only as a subjective notion but also as an ordinal notion allowing describing preferences (Varian, 2009). However, while it is assumed that there is no convincing criteria to establish levels of cardinal utility (Varian, 2009), economists have developed methods to establish utility function from which cardinal instantaneous utility function point can be estimated (the utility level at instant t being written

[41] Heal (2000) illustrates the divergence between price and the importance bestowed to good, with the classical diamonds and water paradox. "It perplexed economists through the 18th and 19th centuries until its resolution by Alfred Marshall. (…) Water is clearly more important to human society than diamonds, yet diamonds trade in the market at prices far in excess of those fetched by water (…) because the supply (at least in Marshall's time) was so large as to exceed the amount that could possibly be demanded at any price. Consequently the price was zero; water was free."

U_t). Therefore, some cardinality can actually be introduced in the utility-based (or welfare-based) theory and so between utility and economic value. More precisely, in the case of environmental valuations, economists have developed methods relying on the estimation of functions (more details to follow) that consists either in asking individuals about their preferences/utility and derive monetary estimates, or studying individuals' behaviors and derive monetary estimates.

In both cases, only a variation of individual utility is estimated (Bonnieux and Desaigues, 1998). To measure this variation, two notions are crucial: the individuals' Willingness-To-Pay (WTP) for- or Willingness-To-Accept (WTA) - a change. In case of utility increase, the WTP of individuals is used to secure this (beneficial) change in utility, and in case of utility decrease, the willing to pay (WTP) is used to avoid the (costly) change or the willing to accept (WTA) to let the change happen[42]. Individuals are ready to pay as much as their WTP, or ready to receive as little as their minimum WTA[43], for a change. In the neoclassical approach, WTP and WTA are the necessary increment in income that has to be given or taken from an individual to make him *indifferent* to an exogenous change (Haab and McConnel, 2002).

Some assumptions about individuals' utility are also necessary in this approach to economic value. Individuals' preferences are supposed to be stable (preferences do not change during the period being studied), complete (every good bundle can be compared), reflexive (every good bundle is at least as desirable as itself) and transitive (Varian, 2009). Individuals' utility is also usually supposed to be increasing with consumption at a decreasing rate (hypothesis of decreasing marginal utility) (Bonnieux and Desaigues, 1998) and increasing with income at a decreasing rate (Brent, 2006).

[42] WTA replaces the WTP when the "looser", i.e. the individuals bearing the loss of utility, have legitimate property rights to what they lose (OECD, 2006).
[43] Those two measures are not equivalent however, they can vary significantly (OECD, 2006). See article 3 for more on this point.

2.2.2. The consumer surplus at the basis of the measure of change in utility

This approach finds its roots in the Consumer Surplus (CS) approach. The CS refers to the total satisfaction of a consumer and by extension, when the agent is not a consumer, to the total satisfaction of the individual. A variation of satisfaction will therefore be measured by a variation in CS, and the total economic value of a good by the total aggregated CS of all individuals. If a market price exists, the CS of a consumer equals the maximum amount of money that the consumer would have agreed to pay for the good minus what she/he is actually paying (net CS). If there is no market price, then the CS equals the total WTP of the individual (gross CS).

This means that the good does not worth, for the individual, more than his maximum WTP, and that the individual is indifferent to either, keeping his WTP and not having the good, or having the good and spending his WTP. This measure of the consumer surplus is the "ordinary" measure of the consumer surplus (Bonnieux and Desaigues, 1998), so-called because it uses ordinary (Marshallian) demand curve [BC)[44]. Along this demand curve, the income is stable but utility varies. This ordinary approach to the consumer surplus is only valid, in the case of marketed goods, when the utility function is quasi linear, i.e. when income variations do not affect the demand, and for goods whose demand are not strongly changed by a change in income (Varian, 2009)[45]. While it may be relevant for some environmental goods (such as natural parks valued with the Travel Cost Method, TCM[46]), other measures of the CS can also be relevant because they do not necessarily require using a demand function, which can be hard to establish for those goods. Those measures are the

[44] This curve is derived from a demand function of the individuals established by economists when possible. The demand function expresses the quantity of goods purchased as a function of the main determinants: D = D (Price; Other prices; Income; Tastes…), and the demand curve is derived from this demand function by isolating the effect of changes in price on quantity demanded, holding all the other variables in the demand function constant (Brent, 2006).

[45] In the case of marketed private goods, CV and EV only contain substitution effects (Brent, 2006) and they eliminate income effect. A change in price not only impacts individual utility but also individual real income (so-called the income effect, i.e. lower prices means that the individual's purchasing power has increased, and so more can be spent on all goods (Brent, 2006)). A change in price results indeed in an income effect and a substitution effect (the lower price for the public project means that other goods are relatively more expensive and their consumption will be reduced (Brent, 2006)). To measure the income variation that is equivalent to a change in utility (and obtain a monetary measure of utility), the variation of utility cannot be accompanied by a variation of income. Because the marginal utility of income decreases with the increase of income, a change in income would imply a change in the individuals' scale of valuation.

[46] In the TCM, a recreational demand curve for the site and its environmental characteristics is obtained, after adjustments are made (influence of households income on their number of visit, number of alternative sites,…), and the recreational benefits of individuals are estimated by the consumer surplus (Garrod and Willis, 1999).

equivalent and compensating measure of the consumer surplus. In those measures, the utility is maintained constant and the income varies. Those alternative measures of the CS are relevant in the case of public goods and non-marketed goods because Further on, we will call the compensating measure of a variation in CS the *compensating variation* (CV) and the equivalent/equilibrating measures of a variation of CS the *equivalent variation* (EV). CV and EV estimate the amount of money that would be necessary to give to (WTA) - or take from (WTP) - an individual, for the individual to stay at his original level of utility before the change happened, or to reach the level of utility that he would have reached if the change had happened.

2.2.3. Measuring CV and EV

It is possible to use information about individuals' preferences and income constraint to estimate individuals demand, and it is possible to use information about individuals' demand to obtain information about their preferences (Varian, 2009). Therefore, three functions can be used to do estimate CV and EV, depending on the case and the information available: the compensated and equivalent demand functions, the utility function (or the indirect utility function), and the minimum expenditure function.

Indirect utility. To leave the individual indifferent to an improvement (case 1 in the following table) or a degradation (case 2) of his utility, and therefore to maintain him at the same level of utility, the WTP and WTA will respectively be measured and taken or given so as to 'compensate' him for this change. However, if the change did not occur, the WTA (case 3) or the WTP (case 4) will be measured so as to leave the individual at the same level of utility that he would have been if the change had taken place. Those four theoretical situations are summarized in the table 2, with the following notations: Ut represents the utility function, Yt represents the income function and Et represents the state of the environment. All three vary with the time t, which is reduced here to two periods t = 0 and t = 1.

Figure 7: Compensating and equivalent variation measures

	Compensating variation = Amount of Y that can be taken from an individual *after* a change such that he/she is as well off as they were *before* the change		Equivalent variation = If a change does *not* occur, the amount of Y that would have to be given to the individual to make him/her as well off as if the change did take place	
Increase in human welfare	$U_0 (Y_0 - WTP, E_1) = U_0 (Y_0, E_0)$	(1)	$U_1 (Y_0 + WTA, E_0) = U_1 (Y_0, E_1)$	(3)
Decrease in human welfare	$U_0 (Y_0 + WTA, E_1) = U_0 (Y_0, E_0)$	(2)	$U_1 (Y_0 - WTP, E_0) = U_1 (Y_0, E_1)$	(4)

Source: Pearce et al. (2006)

Those four cases are represented in the two following graphs[47]. Schematically, the utility of individuals is assumed to depend on their consumption of private goods *x* and on the quantity or quality of non-marketed good *z* (like biodiversity, or health in the original graph) they benefit from. The indifference curves are represented on those graphs, and the compensating measure (CV) and equivalent measures (EV) of variation of utility are estimated in terms of the amount of consumption of marketed goods (*x* is equivalent to an amount of money) that have to be given to- or taken from- the individual to compensate change their actual or potential change in utility. The budget constraint is a horizontal linear curve, which does not depend on *z*, the whole income is spent on consumption *x*.

Figure 8: Compensating Variation of the Consumer Surplus

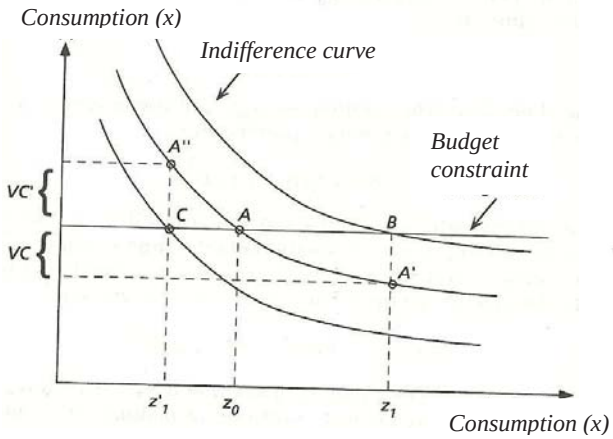
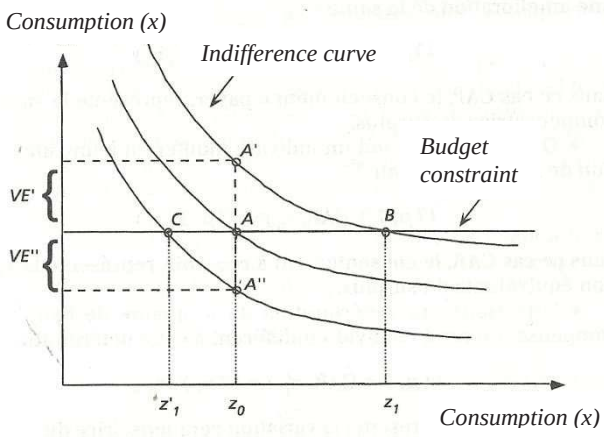


Figure 9: Equivalent Variation of the Consumer Surplus



Source: Bonnieux and Desaigues (1998)

[47] Those graphs were initially in French, and are therefore self-translated.

(case 1) of the figure 8 corresponds to the move in figure 9 from A to B (increase in *z* and therefore in utility) which can be compensating by taking from the individual the amount BA' and bringing the individual back to his original level of utility, at A'.
(case 2) corresponds to a move in figure 9 from A to C (a decrease in *z*) which can be compensated by giving the individual the amount A"C.
(case 3) corresponds in figure 10 to a move that could have occurred from A to B and that would be equivalent to giving the individual the amount AA'.
(case 4) corresponds in figure 10 to a move that could have occurred from A to C and that would be to taking from the individual the amount AA".

In Table 2, the indirect utility function is being used to determine those measures. The indirect utility function is the function V(p,q,y) that gives the maximum utility that can be attained by the consumer with given prices and income (Varian, 2008). Drawing from Haab and McConnel (2002) the basic notations, we can formalize this approach a bit more. U(x,q) is the individual preference function, where x = x1,…,xi,…,xm is the vector of private goods and q = q1,…,qj, …, qn is the vector of public goods[48]. Goods x are available at the prices p = p1, …, pm and the individual possesses the income y. The indirect utility function is therefore given by:

$$V(p,q,y) = \begin{cases} \underset{\{x\}}{Max}\, U(x,q) \\ Subject\ to\ \ p.x \leq y \end{cases}$$

Case (1) of figure 8 for instance, becomes V(p,q*,y-WTP) = V(p,q,y), with q* ≥ q. This WTP gives us the compensating measure of the positive variation of consumer surplus that results from an improvement in the state of the environment from q to q*.

Demand functions. CV and EV use compensated demand functions (Hicksian) and equivalent demand functions instead of Marshallian demand functions. Those demand functions represent the quantity of goods that the consumer can consume/enjoy if he is to stay at the same level of utility but his income varies. They give the baskets of goods that allow the

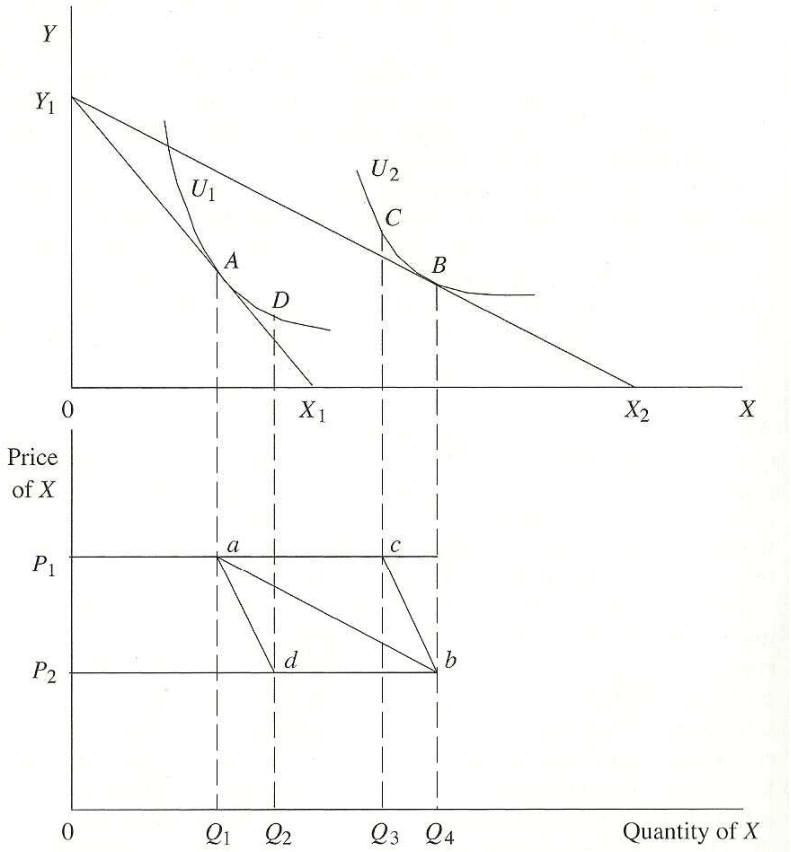
[48] The distinction between x and q rests on whether the individuals controls the quantity not whether there is a market. Individuals choose their x but their q is exogenous (Haab and McConnel, 2002).

individual to reach a certain level of utility at the lowest possible expenses (a basket of good that maximize the utility allows minimize the expenses).

The following graph represents to estimation of compensated and equivalent demand functions as well as CV and EV, resulting from a decrease in the price of good x. This demand function approach requires having some demand functions for environmental goods, which can be obtained via survey or analysis of market behaviors for the goods related to the environmental good to be valued. Indeed, the difference between a public and a private good regarding demand curves is that, for the private good, the industry demand curve is derived by summing horizontally the individual demand curves, while for the public good, social demand is obtained by summing vertically the individual demand curves (Brent, 2006). With private goods, we ask at every price how many each individual demands and sum them in the quantity (horizontal) direction; for public goods, we ask for every unity of quantity how much each individual is willing to pay and sum them in the price (vertical) direction (Brent, 2006).

The introduction of public goods into the analysis requires the modification that it is the area under the social demand curve, and not the market demand curve, that is needed or valuation purposes. However, trying to get to know the social demand curve for public goods poses many practical difficulties (Brent, 2006) as we already mentioned.

Figure 10: CV and EV with demand functions



This diagram shows the consumer response to a fall in price in terms of indifference curves. The budget line swivels from Y_1X_1 to Y_1X_2. The three measures involve different adjustment paths:

Marshallian measure : point *A* to point *B*.
Compensating variation : point *A* to point *D*.
Equilibriating variation : point *C* to point *B*.

The consumer response to a fall in price in terms of demand curves is also shown. The change in consumer surplus is:

Marshallian : in area P_2baP_1
Compensating : in area P_2daP_1
Equilibriating : in area P_2bcP_1.

Source: Brent (2006)

We can compare the relative sizes of the three measures of CS, which are such as: VC<SO<VE for beneficial changes and reverse VE<SO<VC for adverse changes (Bonnieux and Desaigues, 1998; Brent, 2006). The differences between those measures of the CS are important when there is not close substitute for environmental good[49].

[49] The differences between those three measures of the CS depends on the price-elasticity of the income, which can be high in the case of environmental goods, a fortiori when the substitution elasticity is low (there is not close substitute to the environmental good) (Bonnieux and Desaigues, 1998).

Minimum expenditure function. The minimum expenditure function m(p,q,u), it is the function that give the minimum income necessary to reach a given level of utility at given prices (Varian, 2008), which is given by:

$$m(p,q,u) = \begin{cases} \underset{\{x\}}{Min}\ p.x \\ Subject\ to\ U(x,q) \geq u \end{cases}$$

Case (1) becomes WTP = m(p,q,u) – m(p,q*,u) with u = V(p,q,y), which gives the compensating measure of the positive variation of consumer surplus that results from an improvement in the state of the environment from q to q*.

2.2.4. Main monetary valuation methods

The classification of environmental valuation methods is uneasy, as many typological criteria found in the literature overlap or are subjective connoted. However, it is a practical way to review and discuss the fundamental principles of valuation methods.

Market and non-market valuations methods. Champ et al. (2003) define market valuation methods as the methods used when the economic channel though which human well-being is affected is market. Under this definition, the Travel-Cost Method (TCM) ranks among the non-market valuation methods, even though it has recourse to market-based information like the price of entry to the site and the cost of transportation endured by those individuals. Indeed, it is not via some market (no entry price to the natural site) that a change in the environmental state of this natural site will influence individuals' well-being and their decision to visit the site or not. However, some authors do refer to the kind of data being used to value the environmental good or service to define methods as market valuation or non-market valuation methods. De Groot et al. (2002) for instance, consider that all methods using either existing exchange value that goods or services have in trade or existing revealed WTP or WTA of individuals are market valuations methods. Under this criterion, the TCM ranks among market valuation methods, while the Contingent Valuation Method is not because it relies on fictive, debated and/or potentially not exclusively market related information.

Figure 11: non-market valuation methods

Champ et al., 2003	De Groot et al., 2002
Contingent Valuation Method (CVM)	Contingent Valuation Method (CVM)
Attribute-based Methods	Group Valuation Method (GVM)
Multiple good valuation Method	
Travel Cost Method (TCM)	
Hedonic Price Method (HPM)	
Defensive Behavior Method (DBM)	
Damage Cost Method (DCM)	
Benefit Transfer Method (BTM)	

Direct and indirect methods, stated and revealed preferences methods. There are at least three acceptations of the criteria direct/indirect methods. The first acceptation (Markandya, 2001; Chevassus-au-Louis, 2009) assimilates direct methods to stated-preferences methods and indirect methods to revealed-preferences methods. This leads direct methods to be defined as the methods attempting to elicit preferences of individuals for biodiversity by asking them directly those preferences (by stating a monetary value or a preference ordering), within the context of a fictive or hypothetical market (stated preferences methods). Those preferences are not translated in acts. Among those methods, we find methods that value either goods or the attributes of those goods (Champ et al., 2003), either by gathering stated WTP or by using stated choice, ranking and ratings (Champ et al., 2003). As for indirect methods, they are defined as methods attempting to elicit individuals' preferences for biodiversity though the observation of actual, observed, market-related behaviors of individuals about some goods and services related to biodiversity but not directly about biodiversity (revealed preferences methods). (Markandya et al., 2001; Champ et al., 2003). Those behaviors reflect utility maximization subject to constraints and revealed preferences methods involve a kind of detective work in which clues about the values individuals place on environmental services are pieced together from the evidence that people leave behind as they respond to prices and other economic signals (Champ et al., 2003).

Figure 12: Common stated and revealed preferences methods

Revealed-Preferences methods	Stated-Preferences methods
Travel Cost Method (TCM)	Contingent Valuation Method (CVM)
Hedonic Prices (HPM) and Hedonic Wages Methods	Contingent Ranking Method (CRM)
Human Capital Method (HCM)	Choice experiment Method (CEM)
Cost of Illness Method (CIM)	Deliberative Group Valuation Method (DGVM)
Restoration and Replacement Costs Method (RRCM)	Discourse-Based Valuation Method (DBVM)
Preventative / Protection Expenditures Method (PPEM)	
Mitigatory Expenditures Method (MEM)	
Averting Behavior Expenditures Method (ABEM)	

A second acceptation of the criteria direct/indirect methods refers to the reliance or not of those methods on Dose-Responses relationships (Pearce and Turner, 1990). When methods rely on individuals' Demand Curve, they are often considered as direct because they are directly based on individual preferences and not on physical data and when they rely on Dose-Response functions (DR), they are tagged as indirect. Under this acceptation, we can find both stated and revealed preferences methods among direct and among indirect methods. This acceptation draws the same kind of distinction that Schröder et al. (2009) does by discriminating behavioral linkage methods (close to demand-curve based methods) from physical linkages methods (close to dose-responses functions based methods). Depending on the economic school of thought (Classic Economics, Marxist Economics, New/Neoclassical Welfare Economics[50], Institutional Economics, Ecological Economics, Evolutionary Economics …); either category is considered to be more relevant than the other. Pearce and Turner (1990), Turner et al. (1994), Dosi (2000) and Neoclassical Welfare Economists for instance, favor methods relying on demand-curve and therefore call those the direct methods. Then, direct methods can be the methods which focus straightforwardly on the monetary value of biodiversity without having to deduce this value from some market-related information existing about goods and services related to biodiversity (for revealed preference methods) or from some choice, ranking or rating information stated about biodiversity's goods or attributes (for stated preferences methods). They depend on the direct information about prices and quantities (Bishop and Heberlein, 1979), i.e. the exchange value that environmental good have in trade (De Groot et al., 2002).

Cost-based methods. One can distinguish between cost-based and price-based methods (TEEB, 2010), or between cost-based and other valuation methods (Chevassus-au-Louis,

[50] Gowdy (2004), NWE.

2009; SCBD, 2010; TEEB, 2010b; Dosi, 2000) within monetary valuation methods. Price-based methods are those using some existing market prices (TEEB, 2010) whether there are efficient or distorted (Markandya et al., 2001), and cost-based methods are those using proxies about markets values ("market signals", Champ et al., 2003) that are directly about the environmental good or service but that are not market prices (also called objective valuation methods by Markandya et al., 2001). The Replacement Cost Method for instance ranks among cost-based methods; it assesses the costs of replacing damaged environmental assets (Markandya et al., 2001) by human-made goods and services. However, not all valuation methods using costs in their estimation are cost-based methods. As Markandya et al. (2002) suggest it, valuation methods relying on costs that are not directly resulting from an environmental change are usually not ranked among cost-based methods. The Travel-Cost method (TCM) and the Hedonic Prices Methods (HPM) are therefore not ranked among cost-based methods (Garrod and Willis (1999), Dosi (2000), Markandya et al. (2001), Markandya et al (2002), Chevassus-au-Louis (2009), TEEB (2010)), whereas the Replacement Costs method or the Averting Behavior methods are ranked among cost-based methods.

Figure 13: Some cost-based methods

Effect On/ Change in Production/Productivity (EOP)
Opportunity Costs Measures (OC)
Human Capital (HC), Cost of Illness (COI), Loss of earnings and Dose-Response functions (DR)
Replacement, Restoration, Relocation Cost (RC)
Preventative Expenditures (PE)
Mitigatory Expenditures / Mitigation Costs
Averting Behavior (AB)
Avoided Cost

Source: adapted from Garrod and Willis (1999), Markandya et al. (2001, 2002), Chevassus-au-Louis (2009).

3. The relevance of monetary valuations of biodiversity for public decision and policy making: presentation of the essays

As we saw, biodiversity losses represent a threat for human societies, and monetary valuations have been developed in order to inform decision making about the benefits and costs of biodiversity losses is the monetary valuation. Monetary valuations are introduced by their proponents as tools helping to introduce biodiversity issues into account into public

decision making. The rationale usually used to justify the usefulness of valuations for public decision making, is summarized by Folmer and Ierland (1989):

> Public policies and projects must address the two fundamental issues of resources allocation and property-regimes. A clear discrepancy exists between private costs and social costs of environmental degradation, which can be explained by the fact that using the environment costs almost nothing to private producers because it has no price (therefore a price of zero). The prices of the goods produced using some environmental inputs are therefore lower (and relative prices distorted) that they should be (scarcity should increase those prices), while the demand for those goods is too high because price signals are wrong. This leads to an overproduction of pollution-intensive products and a degradation of the environment. The idea is then to transform the environmental scarcity to signals, used then in control mechanisms, which should reduce the divergence of private and social costs. Those signals cannot come from the market because environment is a public good, so methods have to be developed to provide some signals, valuations, in the absences of prices. The optimal allocation of the production factors labor, capital and environment depends on the correct valuation of the environment.

This vision is the theoretical starting point for many valuations' authors, and it sees monetary valuations as the information supposed to play the role that prices cannot play in the case of environmental changes, i.e. providing estimates of the economic value of the environment for society, and more restrictively of the benefits and costs of environmental changes for society.

However, the relevance of traditional monetary valuations applied to biodiversity is controversial and vividly debated, between economists of different doctrines but also between scientists of different disciplines, as biodiversity issues requires interdisciplinary research. Valuations appear for some authors as a tool whose approach is too close to the financial profit seeking approach of the private sphere, responsible for biodiversity losses. The argument that monetary value of biodiversity are required to allow public decision makers is also not well-accepted, as it suggests that only the monetary value of biodiversity counts and that what counts can be monetarily valued.

This PhD attempts therefore to investigate the fundamental grounds of disagreements between proponents and opponents to valuations, and in particular to neoclassical monetary valuations.

Because the relevance of valuations depends on numerous factors that this PhD cannot all cover, we decided to focus mainly on the grounds that are related to valuations' content and the legitimacy of this content, leaving aside other sources of relevance and legitimacy.

Our initial hypothesis is that monetary valuations studies do not really deal with biodiversity per se, which would explain why strong disagreements between economists and other sciences emerge. To test this hypothesis and develop other hypothesis, we first investigate valuations' expected roles (article 1) according to the literature, and criticisms of those roles. It appears that the first hypothesis ranks among the plausible grounds of disagreements and valuations' limited relevance. However, at this stage of research, we cannot yet discuss the veracity of this hypothesis. We will wait the article 4 to do so. But a second hypothesis emerges that we investigate in the second part of article 1.

The intensity of the disagreements about - and advocacies for - valuations' relevance suggest that not only technical and instrumental reasons related to the content of valuations are aimed at by supportive and critical comments. After trying in the first part of the article to categorize the expected roles of valuations, we realize that valuations are expected to actually play two types of roles, rather than only the objective instrumental role that Ierland and Folmer (1989) suggest. They are expected to play a role of support for decision-making and management and a role of information, sensitization and conviction about an issue.

The simultaneity of both makes the objectivity of valuations at risk, and appears as a possible explanation of the origins of critics denouncing valuations as influential dominant tools. This justifies studying the legitimacy of valuations' content in the rest of the article, and this dimension of sensitization role and influential power. This is why the second part of the article deals with those, and particularly with two dimensions of valuations that triggers many of the criticisms regarding the influential power of valuations: their incorporations into CBA and the recourse to the monetary unit for realizing them.

After underlining the existence of an often neglected normative, subjectivity or at least partiality, and influential power in valuations, we realized through reading and conferences' meetings that not only the influential power of CBA and the recourse to the monetary unit are neglected, but also some fundamental principles and assumptions of valuations. This is

plausible in a context of interdisciplinary research, in which communication between sciences is made difficult by the complexity of each approach, but also appears to be useful for helping clarify and discuss assumed and often implicit principles of the economic theory.

Therefore, the rest of this PhD attempts to investigate some of the fundamental assumptions valuations are based on, that are not necessarily at the center of usual discussions on valuations because they are not really technical, they are almost axiomatic. We think that they are fundamental to grasp the essence of what monetary valuations are and what type of information about biodiversity they can bring. Even for economists, such an approach seems pertinent because monetary valuations of biodiversity rely mostly on the mainstream economic current of thoughts, neoclassical economics, which does not resume what economics, and therefore valuations are and could be about.

One of those assumptions has to do with the environmental ethics that monetary valuations adopt toward biodiversity. Indeed, valuations are easily resumed as instrumental and anthropocentric, and on this ground they may be rejected by other non-economists scientists because they are reductive. Their ethical approach is also a matter discussed in the debates between economists, for instance when they debate about the capacity of valuations to estimate so-called non-use values. Because valuations can benefit, as we see in article 1, from some influential power, it is crucial to ensure that they can, by essence, provide the information they are expected to provide. And so we explore in article 2 the well-accepted definitions of economics, the definitions of anthropocentrism and instrumentality, and the eventual shift in ethical approach that monetary valuations can bring to the economic analysis.

To continue underlining the importance of ethical assumptions for valuations' relevance, we focus on a stage of valuations that is often seen as technical, discounting. Focusing on this particular aspect of valuations rather than another is justified by the fact that biodiversity losses have consequences over a long time, which almost immediately imply in economics dealing with discounted valuations. So we discuss the ethical and normative implications of the mostly used exponential discounting method, and to do so, we rely on an interdisciplinary literature, illustrating the point we made earlier that other sciences may help to question assumed and implicit assumptions.

We further confront exponential discounting to an alternative method of discounting, hyperbolic discounting, because many empirical evidences suggest that hyperbolic may be more representative of the way humans deal with temporal trade-offs, potentially making hyperbolic discounting more relevant for public decision makers than exponential discounting. We see in this article again that the legitimacy of content is at least as important as the content for making valuations' relevant, as hyperbolic discounting may be closer from real human behaviors, but may not be the appropriate way to discount social benefits derived from biodiversity. What is does not necessarily reveals what ought to be, and public decision makers need to be informed about what is but they ought to keep choosing what to be.

Finally, after exploring some reasons for a limited relevance of valuations for public decision makers mainly related to the economic theory (the influential and normative power of CBA and the monetary unit, the shift in ethics that monetary valuations bring to the general economic approach to biodiversity, the limits of exponential but also hyperbolic discounting), we investigate some reasons for the limited relevance of monetary valuations of biodiversity that are more related to the object of study itself, biodiversity. This way, we come back to our first hypothesis.

Indeed, we realize that biodiversity has actually an undetermined economic status. Biodiversity is often considered as a known type of good, service, asset or resource while actually it is not a neither of those, but rather a property and a process simultaneously. Valuations of biodiversity suffer from the fact that biodiversity is a complex notion, already for natural sciences. The recourse to traditional monetary valuation methods for valuing biodiversity is therefore irrelevant if seen and understood as such. For this reason, this last article explores the dimensions of biodiversity that may be covered by monetary valuations. To do so, we analyze the definition of biodiversity, the economic status that biodiversity has so far enjoyed, and fundamental principle of the main valuations methods. Their confrontation provides some insights for discussing the legitimacy of valuations to value biodiversity, and the legitimacy of valuation's content depending.

REFERENCES

AMARA Rachid (2010), « Impact de l'anthropisation sur la biodiversité et le fonctionnement des écosystèmes marins. Exemple de la Manche-mer du Nord », *VertigO*, Hors-Série 8.

AULONG Stéphanie, Katrin ERDLENBRUCH and Charles FIGUIERE (2005), « Un tour d'horizon des critères d'évaluation de la diversité biologique », *Economie Publique*, No.16.

BARNAUD Cécile, ANTONA Martine and MARZIN Jacques (2011), « Vers une mise en débat des incertitudes associées à la notion de service écosystémique », *Vertigo*, Vol.11, N.1.

BISHOP Richard C. (1978), "Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard", *American Journal of Agricultural Economics*, Vol.60, No.1.

BONNIEUX François and DESAIGUES Brigitte (1998), Economie et politiques de l'environnement, Ed. Dalloz, Coll. Précis Dalloz Sciences Economiques, Paris.

BREKKE Kjell Arne (1997), Economic growth and the environment: on the measurement of income and welfare, Edward Elgar, Cheltenham, UK, Lyme, US.

BRENT J. Robert (2006), Applied Cost-Benefit Analysis, 2nd Edition, Edward Elgar, Cheltenham UK, Northampton, MA, USA.

BROMLEY Daniel W. (2006), Sufficient reason: volitional pragmatism and the meaning of economic institutions, Princeton University Press.

CARDINALE B.J., SRIVASTAVA D.S., DUFFY J.E., WRIGHT J.P., DOWNING A.L., SANKARAN M. and ROUSSEAU C. (2006), "Effects of biodiversity on the functioning of trophic groups and ecosystems", Nature, Vol.443, N.26.

CEQ (Council on Environmental Quality) (1993), "Incorporating biodiversity considerations into environmental impacts analysis under the national environmental policy act", NEPA (National Environmental Policy Act), Washington.

CHAMP Patricia A., BOYLE Kevin J. and BROWN Thomas C. (2003), A primer on non-market valuation, Kluwer Academic Publishers.

CHEVASSUS-AU-LOUIS Bernard (Rapporteur) (2009), « Approche économique de la biodiversité et des services liés aux écosystèmes: Contribution à la décision publique », CAS (Conseil d'Analyse Stratégique).

DE GROOT Rudolf S, WILSON Matthew A., BOUMANS Roelof M.J. (2002), "A typology for the classification, description and valuation of ecosystem functions, goods and services", *Ecological Economics*, pp.393-408.

DUNLAP Riley E. and SCARCE Rik (1991), "The polls-poll trends: environmental problems and protection", *Public Opinion Quarterly*, Vol.55, pp.651-672.

EHRLICH Paul R. and EHRLICH Anne H. (1992), "The value of biodiversity", *Ambio*, Vol.21, N.3, pp.219-226.

FARBER Stephen C., Robert COSTANZA et Matthew A. WILSON (2002), "Economic and ecological concepts for valuing ecosystem Services", *Ecological Economics 41*, pp.375–392.

FARLEY Joshua (2008), "The Role of Prices in Conserving Critical Natural Capital", *Conservation Biology*, Vol.22, No.6, pp.1399–1408.

FLEURY Cynthia and PREVOT-JULIARD Anne-Caroline (Ed.) (2012), L'exigence de la réconciliation, Ed. Fayard

GARROD Guy and Kenneth G. WILLIS (1999), Economic Valuation of the Environment: Methods and Case Studies, Edward Elgard.

HAAB Timothy C. and McCONNEL Kenneth E. (2002), Valuing environmental and natural resources : the econometrics of non-market valuation, Edward Elgar, Cheltenham, UK, Northampton, MA, USA.

HAMILTON Lawrence C. and BUTLER Melissa J. (2001), *Human Ecology Review*, Vol.8, N.2, pp.1-11.

HAMILTON Lawrence C., HAEDRICH Richard L. and DUNCAN Cynthia M. (2004), "Above and Below the Water: Social/Ecological Transformation in Northwest Newfoundland", *Population and Environment*, Vol.25, No.3, pp.195-215.

HANSSON Sven O. (2002), "Les incertitudes de la société du savoir", *Revue internationale des sciences sociales*, Iss.1, N.171.

HARDELIN Julien, KATOSSKY Arthur and MARICAL François (2010), « Pourquoi et comment monétariser l'environnement? », in « Donner une valeur à l'environnement : la monétarisation, un exercice délicat mais nécessaire », *La Revue du CGDD (Commissariat Générale au Développement Durable)*.

HEAL Geoffrey (2004), “Economics of biodiversity, an introduction”, *Resource and Energy Economics* 26, pp. 105-114.

HEAL Geoffrey (2000), « Valuing Ecosystem Services », *Ecosystems*, pp.24–30.

HEYWOOD V.H. and WATSON R.T. (Ed.) (1995), “Global Biodiversity Assessment”, United Nations Environment Program Cambridge University Press.

HOOPER D.U., CHAPIN III F.S., EWEL J.J., HECTOR A., INCHAUSTI P., LAVOREL S., LAWTON J.H., LODGE D.M., LOREAU M., NAEEM S., SCHMID B., SETÄLÄ H., SYMSTAD A.J., VANDERMEER J. and WARDLE D.A. (2005), “Effects of biodiversity on ecosystem functioning: a consensus of current knowledge”, *Ecological Monographs*, Vol.75, N.1.

FOLMER Henk and IERLAND Ekko Van (1989), Valuation methods and policy making in environmental economics, *Studies in environmental Science* 36, Elsevier Science Publishers.

LENTON Timothy M., HELD Hermann, KRIEGLER Elmar, HALL Jim W., LUCHT Wolfgang, RAHMSTORF Stefan, and SCHELLNHUBER Hans Joachim (2008), “Tipping elements in the Earth’s climate system”, *PNAS*, Vol.105, N.6, pp.1786–1793.

LIMBURG Karin E., O’NEILL Robert, COSTANZA Robert and FARBER Stephen (2002), “Complex systems and valuation”, *Ecological Economics*, N.41, pp.409–420.

MARIS Virginie (2010), Philosophie de la biodiversité : petite éthique pour une nature en péril, Buchet-Chastel.

MARKANDYA Anil, PERELET Renat, MASON Pamela et TAYLOR Tim (2001), Dictionary of environmental economics, Earthscan (Ed.)

MAY Robert M. (2010), "Why should we be concerned about loss of biodiversity?", Académie des sciences, 9 février 2010, Conférence-débat "La biodiversité face aux activités humaines", http://www.academie-sciences.fr/video/v090210.htm

MEA (MILLENIUM ECOSYSTEM ASSESSMENT) (2005), Ecosystems and Human Well-being, Synthesis, Island Press, Washington DC.

MEADOWS Donella (1998), “Indicators and Information Systems for Sustainable Development”, A Report to the Balaton Group.

MEINARD Yves (2011), L’expérience de la biodiversité: philosophie et économie du rapport à l’environnement, Ed. Hermann.

NORGAARD Richard B. (2010), “Ecosystem services: From eye-opening metaphor to complexity blinder”, *Ecological Economics*, N.69, pp.1219–1227.

NUNES Paulo A.L.D. et Jeroen C.J.M. VAN DEN BERGH (2001), “Economic valuation of biodiversity: sense or nonsense?”, *Ecological Economics*, No.39, pp. 203–222.

OECD (Organisation for Economic Co-operation and Development) (1993), “OECD core set of indicators for environmental performance reviews”, *OECD Environment Monograph*, N°83, Paris, France.

OSTROM Elinor (1995) “Designing complexity to govern complexity”, in HANNA Susan and MUNASINGHE (1995), Property rights and the environment: social and ecological issues, Ed. ESD.

PATTANAIK P.K. and XU Y. (2000a), “On diversity and freedom of choice”, *Mathematical Social Science*, N.40.

PATTANAIK P.K. and XU Y. (2000b), “On ranking opportunity sets in economic environments”, *Journal of Economic theory*, N.93.

PEARCE David, ATKINSON Gilles and MOURATO Susana (2006), « Cost-Benefit Analysis and the Environment: recent developments», OECD press.

PEARCE David W. and TURNER Kerry R. (1990), Economics of natural resources and the environment, Harvester Wheatsheaf.

RISHER Peter and MARKOW Dana (1998), “Biodiversity in the Next Millennium”, poll conducted for the American Museum of Natural History by Louis Harris and Associates.

SCBD (Secretariat of the Convention on Biological Diversity) (2010), “Global Biodiversity Outlook 3”, Montréal, 94 pages.

SCHRANK William E. (2005), “The Newfoundland fishery: ten years after the moratorium”, *Marine Policy* N.29, pp.407–420.

SCHROEDER Jantine, TURCANU Catrinel, VANDENHOVE Hildegarde et CARLE Benny (2009), « Environmental Valuation », SCK-CEN (Studiecentrum voor Kernenergie/Centre d'Etude de l'Energie Nucléaire), External Report, No.111.

SCOONES I. (1999), “New ecology and the social science: what prospects for a Fruitful Engagement?”, Annual Review of Anthropology, N.28, pp.479-507.

SEN Amartya (1999), Commodities and capabilities, Oxford India Paperbacks, Oxford University Press.

SINGH J.S. (2002), "The biodiversity crisis: A multifaceted review", *Current Science*, Vol.82, N.6., pp.638-647.

STERNER Thomas and VAN DEN BERGH Jeroen (1998), "Frontiers of Environmental and Resource Economics", *Environmental and Resource Economics*, Vol.11, Iss.3-4, pp.243–260.

TEEB (2010), The Economics of Ecosystems and Biodiversity: Ecological and Economics Foundations, Ed. Pushpam KUMAR, Earthscan, London and Washington.

TURNER R. Kerry, PEARCE David and BATEMAN Ian (1994), Environmental Economics: an elementary introduction, Harvester Wehatsheaf.

VARIAN Hal R. (2009), Introduction à la microéconomie, 6th Ed., Ed. De Boeck, Bruxelles.

WALLINGTON Tabatha J., HOBBS Richard J. and MOORE Susan A. (2005), "Synthesis Implications of Current Ecological Thinking for Biodiversity Conservation: a Review of the Salient Issues", *Ecology and Society*, Vol.10, N.1.

WEESIE Peter and Jelte VAN ANDEL (2003), "On Biodiversity and its Valuation", CDS Report Series.

WEGNER Giulia and PASCUAL Unai (2011), "Cost-benefit analysis in the context of ecosystem services for human well-being: A multidisciplinary critique", *Global Environmental Change*, N.838.

WEITZMAN Martin L. (1992), "On diversity", *The quarterly journal of economics*, N.107, Issue 2, pp.363-405.

WEITZMAN Martin L. (1998), "The Noah's ark problem", *Econometrica*, Vol.66, N.6, pp.1270-1298.

WILSON E.O. (2002), The future of life, New York: first vintage books edition.

WILSON E. O. (Ed.) and FRANCES M. Peter (Ass. Ed.) (1988), Biodiversity, National Academy Press, Washington D.C.

WORM Boris, BARBIER Edward B., BEAUMONT Nicola, DUFFY Emmett, FOLKE Carl, HALPERN Benjamin S., JACKSON Jeremy B. C., LOTZE Heike K., MICHELI Fiorenza, PALUMBI Stephen R., SALA Enric Sala, SELKOE Kimberley A., STACHOWICZ John J. Stachowicz and WATSON Reg (2006), « Impacts of biodiversity loss on ocean ecosystem services », *Science*, Vol.314.

ZACAI Edwin (2012), “Over two decades in pursuit of Sustainable Development: Influence, transformations, limits”, *Environmental Development*, N.1, pp.79–90.

ESSAY 1. Expected roles of monetary valuations of biodiversity and their neglected normative and influential powers

Abstract

The field of environmental valuations has been flourishing and trying to help cope with biodiversity losses issues rationally. This article initially explores the various roles that monetary valuations could play in dealing with this crisis according to the literature, and reconsiders those roles. While strong enthusiasm for monetary valuations exists in economics and other sciences, strong criticisms of those valuations' theoretical foundations and ethical implications also exist, persist and continue to emerge. Then, it suggests that some non-technical dimensions of valuations play a significant role in the debates around the relevance of valuations, and that two of those dimensions are valuations' normativity and valuations' influential power on human behaviors (including decision making). Looking for the roots of such normativity and power, we find some well-known and criticized aspects of mainstream neoclassical economics (among which we choose to analyse further more the Cost Benefit Analysis (CBA)), but also some more fundamental and basic component of valuations such as the recourse to the monetary unit. The conclusion advocates for more transparency about the normative dimension of monetary valuations and CBA for the benefit of decision makers, and for more awareness about the subjective and potentially powerful influence that valuations may have on human behaviors. Those two steps are necessary for framing the recourse to monetary valuations and CBA in the case of biodiversity related issues, and for making it legitimate.

1.1. Introduction

For some authors, monetary valuations of an object are expected to improve the understanding and knowledge we have of this object. While it is often implicit that the knowledge we get from valuations is about the economic significance of the object,

mainstream economics' terminology tends to overreach its prerogatives. For instance, monetary valuations are expected to reveal and prove the importance of an issue (Bräuer, 2003) and therefore to prevent us from neglecting it (Bullock et al., 2008); they are expected to quantify objects in order to make them more 'transparent' (understandable for economists?) and allow them to be taken into account (Garrod and Willis, 1999). Valuations can also be introduced in more contained terms and be are expected to provide useful economic information to understand the situation (Allen and Loomis, 2006; Arrow et al, 1993; Balmford et al., 2002; Beaumont et al., 2008; Bräuer, 2003; Chevassus-au-Louis, 2009; Ledoux and Turner, 2002) and to make some further inquiries about the issue (Bullock et al., 2008; Bonnieux and Desaigues, 1998; Emerton, 2005; Nunes and Van Den Bergh, 2001).

Those improvements in knowledge are then expected to facilitate actions and decisions, and to increase the quality of the latter. Indeed, valuations are expected to supply the appropriate data for particular needs, to document alternative options, and to audit and monitor. And they can indeed allow the use of economic tools, the constitution of a guarantee fund (Bonnieux and Desaigues, 1998), the establishment of green accountability (Braüer, 2003; Chevassus-au-Louis, 2009), and potentially help guiding actions and strategies (Beaumont et al., 2008) by enabling arbitrages, choice of orientations (Chevassus-au-Louis, 2009) and of best options (Bateman and Willis, 2001; Emerton, 2005). In this last examples of valuations' use (guiding decision in order to choose the best option), we face again the tendency of modern economics to regard monetary valuations as the necessary and sufficient information to make decisions, which our study of the CBA later will document.

While identifying the expected roles of monetary valuations, we realized that actually two categories of roles attributed to valuation exist: a role of information, sensitization and conviction about an issue, and a role of support for decision-making and management[51]. Obviously, it is difficult in practice to classify valuations' roles precisely into these two categories, because they are interdependent. Decision-making requires ongoing information updates, and those updates can influence drastically decision-making and potentially sensitize decision-makers to new issues. Showing the economic valuation of biodiversity can change the process of government and popular perception (Pearce and Moran, 1994). However, this article will use those two categories while analyzing in its first section researchers' statements

[51] Recalling the "management problem" of Freeman, in Champ et al, 2003.

and criticisms about the usefulness of monetary valuations, because those statements fit somehow in those categories.

Thereafter, this paper will move beyond this category distinction. As such, the first category of valuations' roles (informing, sensitizing and convincing) allows for some subjectivity in the influence valuations can have on people while the second category (role of support for decision-making and management) does not, and rather appears fundamentally objective and strictly instrumental. Indeed, only the roles of the first category (see section 1) refer to such terms as 'improving acceptance', 'developing a feeling of responsibility', 'justifying protection' and 'making aware'. By contrast, the second category is rather technical with terms such as 'calibrating instruments', 'accounting' or 'compensation'.

A tension exists therefore, between monetary valuations being on the one hand influential communication tools and on the other hand, valuations being objective instrumental tools. This suggest that in practice, valuations might see their both types of roles intertwined, which would result in making valuations influential tool for the decision-making and management processes, beyond the strictly instrumental role they are often spoken of for. We emphasize two possible reasons (among other) for this coexistence of roles and the resulting influencial power that valuations can have. One reason is doctrinal and has to do with the unassumed normativity of the neoclassical doctrine, the other reason is even more fundamental and has to do with the choice of the monetary unit for valuing biodiversity.

Therefore, sections 2 and 3 of this essay deal respectively with the monetary unit and with CBA (one way of using valuations strongly representative of the doctrinal normativity of neoclassical economics), and investigate the normativity and the influential power that they both provide to monetary valuations. In a context of simultaneously, growing recourse to – and growing concern about – monetary valuations and CBA, debates and studies about their legitimacy and applicability are necessary (Wegner and Pascual, 2011) and we hope that this article contributes to it.

1.2. Expected roles of monetary valuations of biodiversity

After the elaboration (1992) and signature (1993) of the Convention on Biological Diversity (CBD), public agencies were especially motivated to measure biodiversity (Spash and Hanley, 1995). In this context, monetary valuations and CBA appear to stand as good alternatives to Environmental Impact Assessments (EIA), and as necessary tools to justify the costs resulting from biodiversity protection policies and projects (Spash and Hanley, 1995)[52]. Valuations and CBA have been being increasingly used to evaluate projects and policies that affect biodiversity and ecosystem services, and to guide selection or projects that deliver maximum net benefits to society (Wegner and Pascual, 2011). However, this particular use of valuations in the selection of policies and projects should not hide other potential uses that valuations may have, and that should not suffer from criticisms addressed to the common use of valuations into CBA. We review for now those expected and attributed roles to valuations, without discussing them yet, and we classify them into two categories.

First, monetary valuations are often introduced as tools having a *sensitizing, informing and convincing* role, aimed at raising the awareness of individuals (including policy-makers) about the dependence of our economy on biodiversity, at expressing individuals' preferences regarding biodiversity management and at providing incentives to public and private organizations to act in favor of its conservation.

- Monetary valuations, once compared to society's actual spending on biodiversity conservation, reveal how much we really care about biodiversity and the extent to which we under-invest in its conservation (Pearce, 2007). Without monetary valuations, we might under-valuate biodiversity and as a result under-invest in its conservation (Balmford et al., 2002).
- Monetary valuations help to understand (Arrow et al., 1993; Bräuer, 2003; Beaumont et al., 2008) and prove (Bräuer, 2003) the importance of biodiversity for our economy, and among other things the importance of the Goods and Services it provides (Bräuer, 2003). For the ecology experts Ehrlich and Ehrlich (1992), monetary valuations are necessary because humans only feel responsible toward known species while they should care for the whole functioning system.

[52] The term *justify* here means that 'knowing' what the benefits human derive from biodiversity are allow us to realize that the costs of protection biodiversity worth to be borne, because of the benefits that those costs help to preserve.

- Monetary valuations force us to acknowledge and be aware of the importance of biodiversity for our economy (Salles, 2010), even if those monetary valuations are not accurate (Beaumont et al., 2008), and they provide the incentive for (Balmford et al., 2002; Heal, 2000) – and justify acting for – (Bräuer, 2003; Pearce and Moran, 1994) biodiversity conservation.
- Monetary valuations reveal in the common language of money/finance supposed to be universally understood by policy-makers, economists, scientists and politicians alike (Beaumont et al., 2008), some economic interests at stake with biodiversity and can demonstrate the profitability (Net Present Value) of some conservation programs (Emerton, 2005).
- For some authors, monetary valuations focusing on people preferences are by their very essence a democratic approach and should be revealed and acknowledged (Nunes and Van Den Bergh, 2001; Wegner and Pascual, 2011).

Monetary valuations can also be introduced as tools playing the role of *aid to management and decision-making*, by providing data as objective and scientific as possible, aimed at being used in monitoring systems (accounting), for calibration purposes (compensation, economic instruments) or for guiding the whole decision process (CBA).

- Monetary valuations can be used for accounting (Bräuer, 2003; Nunes and Van Den Bergh, 2001).
- Monetary valuations help to calibrate and elaborate guarantee funds, projects' budget, grant applications, and economic instruments aimed at biodiversity conservation (Bonnieux and Desaigues, 1998), such as Payment for Ecosystem Services (Laffite and Saunier, 2007). They provide reference values (Salles, 2010).
- Monetary valuations are important for justice (Arrow et al., 1993; CSPNB, 2007), they allow us to estimate damages costs (Bonnieux and Desaigues, 1998), to calibrate monetary compensation for environmental victims in Court and to condemn ES destruction motivated by private interests (Laffite and Saunier, 2007).
- Monetary valuations give a concrete expression to an abstract (Meinard, 2011) or extremely complex notion. They take away the emotional part of the debate around biodiversity losses (Bräuer, 2003).
- Monetary valuations enable decision-makers to integrate environmental considerations in their decisions and to make sustainable decision-making in a market-based

economy (Ledoux and Turner, 2002); so far, decision-makers have undervalued biodiversity issues (Emerton, 2005).

- Because we know more about the costs than about the benefits of environmental policies, monetary valuations of those benefits are extremely important (Garrod and Willis, 1999; Bateman and Willis, 2001). They allow us to weight benefits more, and above all more than zero in CBA (Bräuer, 2003, Bullock et al., 2008, Chevassus-au-Louis, 2009, Nunes and Van Den Bergh, 2001, Maris and Reveret, 2009, Heal, 2000). Neglecting benefits related to biodiversity would lead to biased CBA results and might therefore misguide the decision-making process (Meyerhoff and Dehnhardt, 2007) while monetary valuations of those benefits can change the result of CBA, sometimes in favor of biodiversity (Emerton, 2005).
- Decision-makers need to know the costs and the benefits of their policies (Ledoux and Turner, 2002), i.e. their impact on human well-being (Freeman, in Champ et al., 2003), and not assume them by intuition alone (Garrod and Willis, 1999). Monetary valuations of the ex-ante costs and benefits of public policies on biodiversity are essential (Balmford et al., 2002, Chevassus-au-Louis, 2009, Allen and Loomis, 2006) to give due and appropriate attention to biodiversity issues in CBA (in comparison to other issues), and to make decisions more transparent (Garrod and Willis, 1999), efficient, rational and optimal (Emerton, 2005, Beaumont et al., 2008; Salles, 2010; Freeman in Champ et al., 2003). Under limited budgets, saving biodiversity can be as moral as other missions, and it is necessary to choose the most desirable among those missions (Costanza et al., 1997) and policy options (Bateman and Willis, 2001; Freeman in Champ et al., 2003). Monetary valuations allow reconsidering ex-post the relevancy of previous arbitrages (Emerton, 2005).
- Monetary valuations are key to investment decisions (Pearce and Moran, 1994). They help to favor or disfavor actions aimed at conserving or damaging biodiversity (project, request for funds), and they reveal how biodiversity conservation programs can replace pre-existing uni-dimensional programs such as for instance alleviating poverty (Emerton, 2005). They also reveal which costs can be legitimately engaged in conserving biodiversity because we know the benefits it provides (Maris and Reveret, 2009). Indeed, drastic policies could preserve biodiversity but their costs would be surely rejected, therefore, the estimation of the value of biodiversity for individuals is

relevant in order to determine the degree of efforts in which we want to engage (Maris and Reveret, 2009).

- Monetary valuations help decision-making process regarding natural resources and land-use planning by revealing not only short-term economic interests but also long-term interests (Chevassus-au-Louis, 2009).

To summarize those two categories of roles attributed to monetary valuations, some are provide profit-related (firms' strategies) or efficiency-related (CBA) in support of or against investment in biodiversity conservation. Valuations are assumed to be able to provide convincing representation of the economic value of biodiversity, data for environmental accounting and calibration estimates for environmental trials and for economic instruments. The theoretical and empirical capacity of monetary valuations to actually fulfill those expected functions is however criticized and condemned by numerous authors, within and outside the neoclassical school of thought. In addition, those critiques have gained strength since valuations are applied to biodiversity, and we will review some of them now.

There are criticisms of the actual capacities of monetary valuations to play the first category of role, i.e. to provide sufficiently helpful information about biodiversity. Moreover, there are assertions linking those informative incapacities with monetary valuations' weak relevance and incapacities to sensitize and convince people.

- Monetary valuations are rarely about the importance of biodiversity per se (Beaumont et al., 2008; Nunes and Van Den Bergh, 2001).

  → They stress the economic importance of natural resources and services currently provided to societies, but not the importance of biodiversity.

- Monetary valuations are partial (Bullock et al., 2008); they fail to take into account all the values of biodiversity (Maris and Reveret, 2009; Ludwig, 2000), particularly its social (Boisvert and Vivien, 1998), indirect values (Nunes and Van Den Bergh, 2001), intrinsic and collective values (Wegner and Pascual, 2011). At best they provide lower bounds (Nunes and Van Den Bergh, 2001), at worst inaccurate estimates.

  → They can provide biased, underestimated or inaccurate measures of the value of biodiversity, and therefore they wrongly or insufficiently sensitize, or fail to do so entirely. Money talks but it does not about everything.

- Monetary valuations neglect thresholds (Common, 2007), irreversible effects, complexity, uncertainty and distributional issues (Wegner and Pascual, 2011), and can have at the same time immense impacts on those issues (by making biodiversity scarce for poorer populations or precipitating ecosystems towards tipping points).

  → Some major ecological aspects of biodiversity losses cannot be measured by valuations, which fail to capture some of the most important aspects of biodiversity that people should be sensitized too: the importance of its functioning, the threats its disruption represent.

- Monetary valuations methods based on individuals' preferences may fail to offer any information about environmental impacts or quality (Bräuer, 2003) and cannot be relied on (Spash and Hanley, 1995) because the general public knows little about biodiversity (Spash and Hanley, 1995). They may also build values rather than revealing them (Spash, 2002), especially when the general public is uninformed (Spash and Hanley, 1995), thereby manipulating people' preferences (Boisvert and Vivien, 1998). Moreover, individuals preferences/values measure by WTP and prices (market-related choices) cannot resume all people's values, motivational pluralism and can even less reflect social well-being (Wegner and Pascual, 2011).

  → Monetary valuations not only neglect biodiversity ecological functioning, but also distort if not shape people' preferences which cannot summarize people's value and social well-being.

Regarding monetary valuations as aid to management and decision, criticisms focus on the consequences of those information and sensitization failures and on the lack of relevance of valuations. Schematically, monetary valuations of "bad quality" can lead public decision-makers, public managers and the justice system to make "bad" choices, irrelevant with respect to people's preferences, social priorities and natural constraints. They can also lack relevance for their users, such as actors dealing with accountability, control and monitoring systems, and environmental trials. CBA is a major source of debate, and this section could therefore be easily extended with further criticisms of CBA; however, we will turn to them in section 3. The following points only complete previous and coming criticisms.

- Monetary valuations have little significance because methods have severe internal flaws (Ludwig, 2000). But they also rely on major normative assumptions and choices. CBA focuses on efficiency for instance, which suggests decision making and management process targeting a unique goal. Monetary valuations do not incorporate all dimensions of individual and collective well-being, and are not democratic as they neglect some values, some actors, and some issues.

  → Technical flaws and normative implications of valuations can result in misleading aid to decision-making and management.
- There can be a difficult articulation between juridical rationale and economic monetary valuation (Bonnieux and Rainelli, 1991).
- Remarkably little attention is devoted to examining the assertion that without such monetary valuation ecosystem services are neglected by decision-makers (Gowan et al., 2006), but it seems that the existing use of environmental values in decision-making is very limited (Garrod and Willis, 1999).

All reconsiderations of valuations' role formulated so far could be categorized in two types of criticisms: those targeting the quality of monetary valuations' information, and those targeting the relevance of monetary valuations. There are technical arguments dealing with valuations as instrumental tools, and broader arguments dealing with valuations as tools that may have some normative and subjective influence. To use the approach of Hezri and Dovers (2006), two dimensions participate in the relevance of information: their content and their legitimacy, the two being interrelated. Dealing with the subjectivity and normative dimension of valuations will mean for the next sections, dealing with the content insofar as it plays a role on the legitimacy of valuation, and with the legitimacy. Academic work on monetary valuations of the environment has boomed over the last three decades (Costanza et al., 1997; Deacon et al., 1998; De Groot et al., 2002), often to improve the technical qualities of their methods and results, but also to improve their relevance for public decision-makers (see the MEA and TEEB initiatives for biodiversity). However, Scherrer (2004) still points out that existing tool to measure and manage biodiversity do not yet satisfy simultaneously methodological, ethical, and pragmatic criteria, and that further studies need to be accomplished in this direction. Especially for biodiversity issues which require inter- or trans-disciplinary approaches, to reach this simultaneity requires clarifying the assumptions of

economic valuation methods, which have ethical implications (Gowdy, 1997), and delimitating the conditions of use of valuations and CBA. A great example of a study doing so is the work of Wegner and Pascual (2011), which deals with the recourse to CBA of Ecosystem Services. The following section provides us with some more evidence of this need of clarification.

1.3. Normativity and influential power of money

Some statements about the usefulness and the roles of monetary valuations have to do above all with money characteristics, and only then with monetary valuations. When Ludwig (2000) raises the well-known problem of capturing many complexities with a single measure, he refers to the role of money as a common unit of measure and to its legitimate field of application. Some of those deep-rooted criticisms of monetary valuations actually denounce the often neglected convincing power that money has, and the more than instrumental influence it can have on human behaviors. While Pearce and Moran (1994) acknowledge that ascribing economic value to biodiversity is a powerful argument, the psychological process involved in this power of persuasion is not investigated and it therefore appears in the economic literature as a strictly instrumental and objective informative power. However, some may claim that it is not possible to provide objective and neutral information that does not influence (Spash, 2002), and that in addition, monetary valuations might be more influential. For Kosoy and Corbera (2010), monetary valuations may be more persuasive than non-monetary valuations (Kosoy and Corbera, 2010). This emphasizes a specificity of the monetary unit of account. The following section investigates therefore money's potential to influence individual and collective behaviors, and the normativity of the recourse to the monetary units. Those two elements are assumed to partially explain the strong and widely spread reticence and fierce disagreements about monetary valuations. A summary of the main results concludes the section, and argues for further research investigating the conditions under which the recourse to monetary measures of biodiversity is and is not relevant.

The acknowledgment of money's objective instrumental roles/functions often leads some characteristics of money and monetary valuations to be neglected by economists (Lea and Webley, 2006), even though other human and natural sciences (psychology, sociology,

philosophy, management, anthropology, neurosciences) have developed a large literature on them. Trust is one of the few subjective or emotional aspects of money addressed in economy. However, a broad interdisciplinary literature deals with the issue of how money "enters into human behavior" (Lea and Webley, 2006) and appears to be more than a mere tool. Initially allowing societies to make quicker (Lea and Webley, 2006), more varied and multilateral exchanges (Ingham, 1996), money has since acquired symbolic and social significance (Zelizer, 1989) and has become in our capitalist systems a social object (Carruthers et al, 1998), and an institution (Menger, 1963, in Frankel, 1977). Just as other institutions, which can be understood as manifestations of collective actions (Bromley, 2006), money reflects but also affects the ever-changing relationships between individuals and the society which they compose (Frankel, 1977), and the relationships we have with money itself. Phenomenon like money conservatism (refusal of currency changes, lack of trust in the new money, refusal of what it represents) or restrictions on money use (restrictions on using money as a gift, as a reward for some exchanges, as a way to value some things) (Lea and Webley, 2006) illustrate this point, and force us to look beyond the traditional economic approaches to money to have an enlightened debate about monetary valuations. Zelizer (1989) recounts the classic and traditional approaches of social thinkers to money that seem to prevail in economics today. As an interchangeable and fungible tool, money quantifies the qualities of goods in order to provide a monetary estimate of their value. Therefore, even in the case of goods that seem incomparable as a whole, money is often in modern economics seen as a tool solving this deadlock and providing a parameter of comparison between them[53]. Money has the potential to transform products, relationships, and sometimes even emotions into an abstract and objective numerical equivalent (see Bräuer (2003). In section 1, valuations take away the emotional part of the debate around biodiversity losses). By neglecting the subjective and non-instrumental influence of money on society, and by neglecting the imperfection of money to actually fulfill those functions, traditional approaches to money do not wonder if money actually *can,* and if yes, *should,* be used to measure everything, including biodiversity. However, there are arguments specifically addressing moral (Fiske and Tetlock, 1997) and technical limitations to money's fungibility and widespread use.

[53] Usually, some characteristics of goods can be compared with some criterion, even when they are fundamentally different. However, the comparability between goods taken as a whole is a different process that may or may not be feasible. By providing a monetary estimate for whole goods, money can give the impression to resume the information existing about the good and to provide an exhaustive representation of it. And indeed, monetary measures and especially prices tend in Neoclassical Economics to be regarded as exhaustive information about - and description of - the goods.

If money could perfectly translate all qualities, quantities, values and other components of objects and aspects of individuals, the temptation would be strong to use monetary measures more systematically, for the same instrumental reasons that made money emerge in the first place and made it fulfill its three core functions. However, most authors assume that money cannot translate all values or qualities, recognizing the complexity and richness of human societies and ecological systems. When money cannot, or cannot perfectly, translate all values or qualities, a bias is introduced into the estimation, which individuals can assume to be irremediable and outraging (Fiske and Tetlock, 1997). Fiske and Tetlock (1997)'s model of taboo trade-offs provides us with key concepts and rationales to discuss the impacts of the recourse to monetary measures: it may create a situation of taboo trade-offs. Vigorous debates around the statistical value of life are a great illustration of those taboos trade-offs as a phenomenon in economics. Fiske and Tetlock (1997) conceptualize taboos trade-offs as those choices that appear to be unintelligible and even impossible to make because they require comparing the incomparable, i.e. different types of relationships based on drastically different inherent logics, motives, normative forces, affective tones, moral foundations, metrics, and languages. While decision-makers must handle difficult trade-offs, people not making those decisions (and perhaps even those making the decisions) might reject, ignore – but also misunderstand, be confused, offended or disgusted by – those trade-offs. Fundamentally, Fiske and Tetlock (1997)'s model based on psychological, sociological and anthropological findings reveals the importance that the social order of a society and a culture (shared meanings and models) has for their members, and the extent to which market pricing (MP) language can be rejected when applied to the three other types of social relationships: communal sharing (CS), authority ranking (AR) or equality matching (EM) relationships[54]. Monetary measures and ratios, the basis of market pricing relationships, can be considered to

[54] Those four social relationship models are defined by the authors (Fiske and Tetlock, 1997) as follow. The *Communal Sharing* Model "divides the world into distinct equivalence classes, permitting differentiation or contrast, but no numerical comparison. For example, everyone in a community may share in certain benefits (national defense, police protection) or resources (national parks, clear air) without differentiation, while noncitizen may be excluded entirely". The *Authority Ranking* Model "constructs an ordinal ranking among persons or social goods, thus permitting lexical decision rules. For example, veterans or minorities may be given priority in access to government jobs, or United States federal law may have precedence over state and local laws". The *Equality Matching* Model "is a relational structure that defines socially meaningful intervals that can be added or subtracted to make valid choices. For example, the U.S. can decide to bomb a Libyan army barracks in tit-for-tat retaliation for Libya's sponsorship of the bombing of a U.S. Marine barracks in Lebanon: 1-1=0, which 'even the score'". Finally, the *Market Pricing* Model "is a social structure that make ratio meaningful, so that it is possible to make decisions that combine quantities and values of diverse entities." For example, selecting an investment portfolio based on the fact that it is the investment, among many investments considered, because it maximizes the risk-adjusted return.

undercut, degrade, corrupt, or repudiate the self-images and social identities as moral beings of those using them for relational models other than market pricing; and to subvert, undermine, deprave, and jeopardize the real value of those models and the social order. It hides rather than reveals the importance of those other social relationships (Kosoy and Corbera, 2009). Finally, the authors observe that the intensity of those reactions is a positive function of the distance ("steps") between the two relational models being compared, and a positive function of the downward direction of the comparison. If the normative ordinal ranking of a society corresponds to the following order: Communal Sharing > Authority Ranking > Equality Matching > Market Pricing, then the most difficult trade-offs are the one requiring recourse to MP in order to deal with CS issues (a three-step-downward move).

This model helps us to emphasize and characterize the tensions that can result from using monetary measures and ratios for domains that are not directly market-related. When monetary valuations are required of individuals (declared preferences) or revealed from their behavior (revealed preferences), people may feel forced to allow trade-offs between values (like intrinsic values) via the recourse to the monetary unit on the basis of the argument that trade-offs in decision-making are inescapable (Wegner and Pascual, 2011). Without denying that high opportunity costs trade-offs may be unavoidable (resources are scarce because of demographic and economic growth), Wegner and Pascual (2011) suggest however that a deliberation about those conflicting ethical choices would be more proper than monetary valuations and the technocratic approach of CBA. In the economic literature and especially in neoclassic economics on which most of monetary valuations and CBA are based, rejections of trade-offs between a particular good and income (or other goods) are referred to as lexicographic preferences. For an individual to have lexicographic preference for a particular good means that this good does not enter into the individual's utility function and therefore no indifference surface exists (Spash and Hanley, 1995). In Spash and Hanley (1995)'s study of the existence of lexicographic preferences for biodiversity, 25% of the panel appears to have lexicographic preferences for biodiversity. Interviewees refuse to state Willingness-To-Pay (WTP) for biodiversity protection, and justifies it for the reason that biodiversity should be protected irrespective of the costs. Here, irrespective of the actual feasibility of protecting biodiversity at any costs, a taboo trade-off arises from analyzing a right-based issue. Biodiversity should be protected in its own right irrespective of the cost and the monetary argument. The ethical trade-offs between two ethical commitments cannot be solved with

money. This phenomenon of refusal to state WTP is documented in Contingent Valuation studies, and therein they are called “protest responses to the survey.” They can be treated as “irrational” answers (Ludwig, 2000) and excluded, or forced to fit the monetary equivalence approach (Wegner and Pascual, 2011) even though they might reflect real preferences, such as the refusal to use monetary language for dealing with some spheres and deciding on priorities.

We face here clear limits of the neoclassical economic model to provide realistic and ethically satisfying assumptions. Monetary valuations not only are supposed to reflect market exchanges and exchanges values, but they actually are used to reflect subjective human value, utility (preference satisfaction) and even well-being. In this approach, the value of everything is revealed through market-related choice (Wegner and Pascual, 2011). Not surprisingly because of what precedes, this approach creates taboo-trade-offs situations in which individuals, rather than revealing and constructing individually and collectively their values and thoughts about particular issues, feel oppressed, forced, or cheated. It sparks opposition instead of stimulating a commitment to thinking about difficult issues. We assume that those taboo trade-offs result not only from valuations having normative foundations, but also from the influential power that money can have on human behaviors which we also started to mention.

Indeed, at the root of those tensions and rejections regarding monetary valuations, we also find that the fact (ignored by neoclassical economics), that money has an ambiguous status: It is a powerful tool, more and more sophisticated and omnipresent but also an institutionalized and socialized, imprinted with symbolism, as well as invasive and undesirable (Carruthers and al., 1998) in some spheres (“the indiscriminate intrusiveness” of money (Simmel, in Zelizer, 1989). People’s socialization of their lives and social order does not alone explain their rejection of monetary equivalent. Monetary valuations affix precise numerical values to things, and by creating new equivalences with a unit imprint of significations, they have the potential to change meaning (Carruthers and al., 1998). In addition, the synthetic representation of a thing that a valuation provides necessarily reduces the initial complexity of the thing, and requires selecting the dimensions that are worth taking into account. A fundamental drawback of this selection process is that it necessarily overlooks the non-quantified, and it simplifies and can distort the qualitative complexity of things. Preferences-based valuations for instance consider that any preference being solvent creates values, be

they ecologically and socially desirable and ethical or not (Viveret, 2010). We can refer to section 1, in which some other criticisms of the monism of valuations are provided. If the conversions of Communal Sharing relationships into Market Pricing relationships rank among the most outrageous trade-offs introduced by Fiske and Tetlock (1997), it is precisely because people highly value the qualitative dimensions of communal sharing and do not want them to be reduced and simplified, wrongly translated, or even neglected. They disagree with the belief that arithmetic operations, which can be applied to numbers accurately, can also represent real qualities of the things to which monetary values have been attached (Carruthers et al., 1998), and they disagree with the use of logic and the language of market pricing for dealing with objects for which they have other representations of the way with which they should be dealt. At this point, it would seem highly contradictory to see monetary valuations as democratic (see section 1) as we see that they select the individual preferences that fit the theory[55].

In addition, others reasons explaining the outrage of people regarding an "overuse" of monetary valuations result from the consequences that an increasing recourse to monetary measures can have on people's behaviors and in our societies' functioning. Indeed, norms evolve and what offends current generations today may start to be accepted and integrated as new norm by future generations. Accepting today an unrestricted recourse to monetary valuations is making a choice of society because it is accepting that the monetary sphere gain more and more legitimacy in the future. For Bromley (2006), one of the consequences of the systematic recourse to monetary valuations is the commoditization of everything, and a society that uses more and more "bargaining" type of transactions, and desert rationing and managerial transactions. Then, we also find an aspect that we have not yet addressed of money, which is its empowerment function, resulting from its being a general resource that can serve multiple ends (Carruthers et al., 1998). Money provides and signals power. It also contributes to the evolution of societies toward a more individualistic model (Frankel, 1977), and risks to turn public judgment into selfish individual judgment (Plater and al., 2004) which relates human deaths to any other risks. A reason for this individualism can be that the use of money is far less constrained than the use of other goods; people are less bounded to their communities and local economies. What matters becomes what is monetarily valued, and what is not quantified with money risks being overlooked. One can accept this evolution and

[55] Other arguments exist to support the fact that valuations are not democratic, particularly when they are used for CBA (section 3).

then always argue for more monetary valuations in order to take into account valuable objects (recurrent argument for valuations of biodiversity), or one can at least question the legitimacy of this approach that tend to justify the status quo and legitimize current distributional situations. Section 3 illustrates how the choices of measuring WTP of people results in favoring rich people over poor people.

The empowerment via money is directly linked to another phenomenon that psychologists have analyzed, which is the desire for money in itself, without it being connected anymore to what it is good for (Lea and Webley, 2006). Because of its infinite capacities of application in exchange relations (Simmel in Lea and Webley, 2006), money has partially become a functionless motivator (Marx, Weber, Simmel underlined its potential to become so (Lea and Webley, 2006)) and a unique instrument. Not only studies on money theory but also on discounting force us to acknowledge the fact that money is desired in a different way than the commodities it can buy. Estle et al. (2007) reveal that monetary rewards are not discounted the way consumable rewards are, even though those monetary rewards can perfectly afford those consumable rewards. This disconnection of money from its functions and more particularly from the goods it is supposed to value and help to exchange or buy, contributes to the two main drawbacks of monetary measures we mentioned earlier. One is the neglect of some aspects of the things that those monetary valuations measure. The other is the establishment of trust in the monetary results that may lead to a neglect of the complex raw information on which they are based. It is a property of institutions that they are established, and then taken for granted and partially disconnected from their origins. An ultimate influence of money on human behaviors that is worth mentioning is what psychologists and neuroscientists call the undermining effect of performance-based reward (often monetary). While economists suppose that monetary incentives monotonically increase motivation, Murayama et al. (2010) reveal how monetary performance-based reward can decrease the intrinsic motivation to make an action by emphasizing an objective extrinsic value of the action (and its success) at the expense of the subjective intrinsic value of this action that normally exists as well in individuals. This last point may be crucial for biodiversity. Indeed, once the assumption ‘we need to value monetarily things we want to care about’ is accepted, any dimension of biodiversity not yet taken into account may become the next object to value. And recent research on the valuation of the existence value of biodiversity provides some evidence of this trend.

To summarize, money has been successful in assuming instrumental roles and it has become an empowering market and social institution. As such, it has influenced human behaviors between agents, and toward money, becoming in some situations desired for itself, and disconnected from it actual functions. Because "the more technologies fascinate, the more we are to be cautious in our use of them" (Sicard, 2009), we tried to underline some of those influences. Money has the characteristics of inspiring trust, profit-seeking and individualistic motivations and other behaviors that go beyond the mission to inform. We therefore saw that there are moral (commoditization, individualization of the society, simplification of human relationships, neglect of values and important qualitative dimensions of human life, money as domination tool for some poor populations) and technical (incompleteness, imperfection, wrongness) reasons to fear a systematic recourse to money. Depending on the context, the decision to be made, the term, the actors involved, we need to wonder which services money actually provides (Viveret, 2010) and under which conditions money should be used. This remains to be determined in the context of biodiversity monetary valuations, as those last criticisms of valuations (and implicitly money) show us again:

- The market-based prices tell us the value to society of a small increases or reductions of a service and do not indicate the overall contribution of the service (Heal, 2000). → Valuations are partial.
- Monetary valuations suffer from ecological and economic uncertainties characterizing studies about biodiversity issues (Maris and Reveret, 2009), which are not taken into account in monetary valuations. → Monetary valuations can neglect important aspects of biodiversity issues.
- There can be confusion between different disciplines regarding the notion of value (Bräuer, 2003), between ecology experts and economists for instance, which means that monetary valuations may only represent the financial value of biodiversity and neglect other fundamental aspects of biodiversity like the ethical questions it raises, or its social values (Boisvert and Vivien, 1998)
  → Monetary valuations cannot subsume all values, qualities and issues.

1.4. CBA: additional normativity and influential power

The use of monetary valuations in CBA is a major source of disagreements between authors working on monetary valuations of biodiversity, and it is also one of the most commonly referred uses of valuations. Rather than developing a comprehensive analysis of the theoretical validity and empirical applicability of CBA for biodiversity (see Wegner and Pascual, 2011), this section only investigates some dimensions of the legitimacy and ethics of CBA. It does so to underline the additional normative and influential power that CBA brings to valuations, and it questions the desirability of this extensive recourse to CBA in environmental economics, especially in the context of studying biodiversity.

In brief, the CBA approach is a framework aggregating the costs and benefits of a public projects or policies in order to identify the public actions that is the most desirable. Valuations of the benefits of preserving biodiversity are included in such an approach. CBA are more precisely, aimed at finding the most efficient solutions to policies and projects trade-offs, with a conception of efficiency that dates back from Hicks, Kaldor and Pareto (Pearce et al., 2006). In practice, it is not the Pareto-optimality principle that is applied to define efficiency, but the Kaldor-Hicks compensation principle: a change is efficient if the individuals benefiting from this change can theoretically compensate the individuals loosing from this change and while still benefiting from a net improvement in their well-being though this change (Pearce et al., 2006)[56]. CBA analysis can be done ex-ante or ex-post. For ex-ante cases, it helps to find which public actions to undertake, but it is also used to debate about the desirability of some public objectives, with the efficiency criteria (Pearce et al., 2006). For ex-post cases, it consists in studying the efficiency of a public project or policy after it has been implemented. Concretely, CBA consists of identifying existing policy or project (undertaken if ex-post, or options if ex-ante), quantifying their overall impacts on a predefined system (a local community for instance) through a monetary metric, and identifying positive changes as benefits and negative changes as costs (Pearce et al., 2006; Wegner and Pascual, 2011). The obtained monetary values are then aggregated and discounted to calculate the total net benefit of each policy option in terms of net present value

[56] « This compensation principle was an attempt to broaden the Pareto criterion without making interpersonal comparisons of utility » (Gowdy, 2004).

(NPV) (Wegner and Pascual, 2011) and to calculate Benefits/Costs ratios (Pearce et al, 2006). Those two calculation results are then used to check which policies or projects pass the Kaldor-Hicks compensation test (which means NPV > 0) and to select the policy(ies) or project(s) that bring the highest benefits, i.e. the largest increase in social welfare (Pearce et al, 2006; Wegner and Pascual, 2011).

CBA is therefore a particular way of estimating the desirability of public policies/projects and their objectives, via the recourse to monetary valuations, to value aggregation and discounting, and to the efficiency criteria. The theoretical assumptions of CBA make this approach faces major problems of legitimacy because of its normativity is not admitted. Money allows CBA and so an "objective and realistic evaluation of the economic consequences of different development options" (Brauër, 2003). The value neutrality of CBA is indeed one of the four major reasons why some economists support CBA, according to Wegner and Pascual (2011). But economics is not a value-free science (Bromley, 2006), neither is CBA a fortiori. CBA has the paradoxical mission of covering an extensive variety of dimensions (all kinds of changes in biodiversity values), but with a unique unit (monetary) that will allow aggregation (with more risks of simplification), and for the unique purpose of identifying the most economically efficient choice. It is perhaps not as much the incompleteness of the tool that is criticized and questioned on ethical grounds – any tool has only a particular role to play and need to restrict its approach– than this false assumption that it is neutral, objective, and exhaustive.

CBA is not philosophically neutral (Plater et al., 2004). It is rooted in ethical individualism (social welfare is assessed based on the aggregation of individual subjective utility/preference satisfaction) and endorses methodological individualism: individuals hold their values in advance and can elicit them in isolation (Wegner and Pascual, 2011). This means that CBA does allow dynamic and collective preference formation[57], and does not account for non-consequentialist or non-self-interest values/preferences (like intrinsic, altruistic or ethical preferences) (Wegner and Pascual, 2011). In addition to justifying the monetary order (Bromley, 2006), CBA treats private and social goods and values the same way (Plater et al., 2004) and aggregates them, which might not be socially desirable. Then, CBA not taking into account distributional effects tend to justify, reinforce or neglect the distributional status quo

[57] See the literature on preferences formation, suggesting that not all preferences are already formed and ready to be revealed.

because of its primary focus on efficiency and its exclusive recourse to monetary valuations (WTP and market prices). In addition, prices partly used in CBA can be poor indicators of preferences because of externalities, imperfection of information, and competition, but also behavioral patterns like adaptation and status seeking (Wegner and Pascual, 2011). For instance, the valuation by wealthy tourists of preserved environmental spots may lead a CBA to state as optimal orientation the development of tourism and the exclusion of local people for other competitive uses (Wegner and Pascual, 2011). And when CBA do take into account distributional issues, efficiency and distribution are dealt with separately, and while the elaboration of social welfare function deals with distribution, it cannot avoid being arbitrarily chosen (Wegner and Pascual, 2011). Ultimately, CBA often fails to take distributional issues into account (Pearce et al., 2006).

Many authors acknowledge the subjectivity and non-neutrality of valuations and CBA's economic assumptions (Salles and Pujol, 2010; Pearce and al., 2006) and underline the current limitations of neoclassical economics to deal with biodiversity (TEEB, 2010). Numerous researches on long-term discounting of environmental impacts exist and emphasize the limits (among them ethical limits) of the highly used exponential discounting. However, the use of any discount rate seems to entail potential problems of intergenerational justice, which lead some authors like Wegner and Pascual (2011) to suggest that the recourse to CBA should perhaps be restricted to the assessment of those policies whose impacts do not extend far into the future.

In the context of biodiversity, CBA has to face major challenges: the uncertainty and irreversibility of biodiversity losses, their potential non-substitutability, and biological phenomenon such as thresholds (Common, 2007; TEEB, 2010), long term latencies, and diffuse effects. This restricts drastically the relevance of valuations and CBA, and makes the realization of CBA – which requires complete data of costs and benefits – hard or impossible. Indeed, scientists' lack of knowledge and uncertainty limits our capabilities to make predictions about the costs and benefits of any policies or projects. The following example related to the impact on health of environmental degradation illustrates how the incompleteness of CBA may be damaging.

> *While the Environmental Protection Agency (EPA) of the US could prove that a ban on asbestos would protect against the risks, it could not quantify many*

> *of the benefits of this rule and as a consequence, it could not provide the required information by section 6 of TOSCA[58] law. EPA's decision to ban asbestos could be overturned by the Court for a lack of quantification and an incomplete CBA (Plater et al., 2004).*

One could naturally argue that such an example emphasize the need for more valuations, but the difficulty to gather the information necessary to provide such valuations may prove this argument to be still wrong for some time. Past experiences also reveal how malleable and therefore dangerous CBA may be, especially for making decisions about complex and highly uncertain issues like biodiversity.

> *"As every tool, CBA can either be used to be more environmentally stringent or to be less." In the case of the New Source Review (NSR) of Clean Air Act (CAA), CBA is used as a way to provide more, not less, environmental protection.* (p610) (…) *However, when the anti-regulation activist John Graham[59] imposed the use of CBA for every proposed rule, his intentions were "to dilute or block a wide range of environmental protection measures" (Plater et al., 2004).*

Like for monetary valuations, strong oppositions exist against CBA and even if proponents of CBA seem to agree with opponents about the fact that CBA has to be used in addition to other information, opponents of CBA keep emphasizing this fact. CBA is "too powerful when used alone" (Plater and al., 2004). Like with monetary valuations, fear exists of the power that a tool like CBA could enjoy. We find in the literature warnings about the capacity of CBA to dominate the decision-making process and to be the unique decision criteria (Plater and al., 2004). One finds also criticisms of the dictatorial tone of CBA. Democracy is indeed another major argument used to promote or criticize CBA. Those considering CBA as a tool revealing social preferences promote its use and argue that it might help prevent politicians from using their discretionary power. Those denying the democratic dimension of CBA condemn its use for choosing social objectives, and promote other democratic processes such as public participation and collective deliberation instead. We suggest that what triggers some rejections of CBA finds its roots in the capacity of conviction that CBA has. First, CBA provides a synthesizing result to complex policies trade-offs, which can be attractive for busy decision-makers. Then, its technicality allows it to be advertised as value-free (abstract calculation), despite its actual normativity. It keeps hidden in the price mechanism (Spash,

[58] Toxic Substance Control Act.
[59] Head of the OMB in Bush II White house.

2008 in Wegner and Pascual, 2011) the imperfections and bias of WTP and preferences, which may grants the appearance of a scientific way to deal with ethics. Also, its recourse to the monetary unit, influential itself, also makes CBA look like the perfect tool to decide about budgetary trade-offs. Finally, as Wegner and Pascual (2011) underline, it also convinces of its expediency in market economies, despite evidence revealing how political decisions are actually made, often without CBA.

The evidence of the normativity of CBA indicates that, as for the recourse to the monetary unit, it is necessary to define in which context valuations and CBA can be used. However, the evidence of CBA's influential power and controversial acceptance also suggest that it is necessary to be reminded about the attractiveness of this tool and its causes. Insights from psychology, politics, and management seem particularly necessary to develop caution about our tools and their potentials.

1.5. Conclusion

The combination of monetary (valuations) and synthetic aggregated (CBA) information results in economic evaluations that can have tremendous influence, beyond the strict instrumental role they are supposed to play. A majority of authors in favor of CBA recommend it to be used within the decision-making process in complement of other information. However, this may often neglect the powerful influence that monetary valuations and CBA can have once they are realized and available for use in the decision-making process. Strong reactions against valuations and CBA exist, and this article assumes that they are partially the result of reactions to the normativity of those tools, and partially of their influential power. For policy-makers to use rather than be influenced by those monetary valuations and CBA, the fundamental assumptions behind valuation and CBA methods have to be clear, as well as their ethical implications and their capacity to convince. Only after realizing that can decision-makers decide what their relevance is and how to apply them.

REFERENCES

ACKERMAN Frank and HEINZERLING Lisa (2004), Priceless: On Knowing the Price of Everything and the Value of Nothing.

ALLEN Bryon and LOOMIS John B. (2006), "Deriving value for the ecological support function of wildlife: an indirect valuation approach", *Ecological Economics*, N.56, pp.49-57.

ANDRE Pierre, DELISLE Claude E. and REVERET Jean-Pierre (2003), L'évaluation des impacts sur l'environnement : processus, acteurs et pratique pour un développement durable, 2nd Edition, Presses Internationales Ecole Polytechnique de Montréal, Canada.

ARMSWORTH Paul R., KENDALL Bruce E., and DAVIS Frank W. (2004), "An introduction to biodiversity concepts for ecological economists", *Resource and Energy Economics*, N.26, pp.115-136.

ARROW Kenneth J., SOLOW Robert, PORTNEY Paul R., LEAMER Edward E., RADNER Roy and SCHUMAN Howard (1993), "Report of the NOAA Panel on Contingent Valuation".

ATKINSON Samuel F., BHATIA Sarika, SCHOOLMASTER Andrew F. and WALLER William T. (2000), "Biodiversity impact: Treatment of biodiversity impacts in a sample of US environmental impact statements", *Impact Assessment and Project Appraisal*, Vol.18, N.4, pp.271–282.

BALMFORD Andrew, BRUNER Aaron, COOPER Philip, COSTANZA Robert, FARBER Stephen, GREEN Rhys E., JENKINS Martin, JEFFERISS Paul, JESSAMY Valma, MADDEN Joah, MUNRO Kat, MYERS Norman, NAEEM Shahid, PAAVOLA Jouni, RAYMENT Matthew, ROSENDO Sergio, ROUGHGARDEN Joan, TRUMPER Kate and TURNER R. Kerry (2002), « Economic reasons for conserving wild nature », *Science*, Vol.297.

BATEMAN Ian J. and WILLIS Kenneth (Ed.)(2001), Valuing Environmental Preferences, Theory and Practice of the Contingent Valuation Method in the US, EU, and developing Countries.

BEAUMONT N.J., M.C. AUSTEN, S.C. MANGI and M. TOWNSENDT (2008), "Economic valuation for the conservation of marine biodiversity", *Marine Pollution Bulletin*, N.56, pp. 386-396.

BELLOS Alex (2010), Here's Looking at Euclid, Free Press, 336p.

BISHOP Richard C. (1978), "Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard", *American Journal of Agricultural Economics*, Vol.60, N.1, pp.10-18.

BISHOP Richard C. and Donato ROMANA (1998), Environmental resource valuation: applications of the contingent valuation method in Italy, Kluwer Academic Publishers.

BISHOP Richard C. et Thomas A. HEBERLEIN (1979), "Measuring values of extra-market goods: are indirect measures biased?", *American Journal of Agricultural Economics*, pp.926-930.

BOISVERT Valérie and VIVIEN Frank-Dominique (1998), « Un prix pour la biodiversité, L'évaluation économique entre différentes légitimités », *Natures Sciences et Sociétés*, Vol.6, N.2, pp.17-26.

BONNIEUX François and DESAIGUES Brigitte (1998), Economie et politiques de l'environnement, Ed. Dalloz, Coll. Précis Dalloz Sciences Economiques, Paris.

BONNIEUX François and RAINELLI Pierre (1991), Catastrophe écologique & dommages économiques : problèmes d'évaluation à partir de l'Amoco-Cadiz, Ed. Economica, Paris.

BRAEUER Ingo (2003), "Use of economic valuation for biodiversity conservation", *Agriculture Ecosystems and Environment*, N.98, pp.483-491.

BRITO Daniel (2005), "The importance of sound biological information and theory for ecological economics studies valuing Brazilian biodiversity: A response to Mendonça et al.", *Ecological Economics 55*, pp.5-10.

BROMLEY Daniel W. (2006), Sufficient reason: volitional pragmatism and the meaning of economic institutions, Princeton University Press.

BULLOCK Craig, KRETSCH Conor and CANDON Enda (2008), The Economic and Social Aspects of Biodiversity: Benefits and Costs of Biodiversity in Ireland, Government of Ireland, Dublin.

CAMERER Colin, LOEWENSTEIN George and PRELEC Drazen (2005), "Neuroeconomics: how neuroscience can inform economics", *Journal of Economic Literature*, Vol.XLIII, pp.9-64.

CARRUTHERS Bruce G. and. ESPELAND Wendy N (1998), "Money, Meaning, and Morality", *American Behavioral Scientist*, N.41, pp.1384-1408.

CEQ (Council on Environmental Quality) (1993), Incorporating biodiversity considerations into environmental impacts analysis under the national environmental policy act, NEPA (National Environmental Policy Act), Washington.

CHAMP Patricia A., BOYLE Kevin J. et BROWN Thomas C. (2003), A primer on non-market valuation, Kluwer Academic Publishers.

CHEVASSUS-AU-LOUIS Bernard (Rap.) (2009), « Approche économique de la biodiversité et des services liés aux écosystèmes : Contribution à la décision publique », CAS (Conseil d'Analyse Stratégique).

COMMON Mick (2007), "Measuring national economic performance without using prices", *Ecological Economics* 4, pp. 92-102.

COSTANZA Robert, d'ARGE Ralph, De GROOT Rudolph, FARBER Stephan, GRASSO Monica, HANNON Bruce, LIMBURG Karin, NAEEM Shahid, O'NEILL Robert V., PARUELO José, RASKIN Robert G., SUTTON Paul, VAN DEN BELT Marjan (May 1997), "The value of the world's ecosystem services and natural capital", *Nature*, Vol. 387, p253-260.

CSPNB (Conseil Scientifique du Patrimoine Naturel et de la Biodiversité) (2007), Eléments pour un appel à propositions de recherche sur l'évaluation prospective des écosystèmes, 6p.

DEACON Robert T., DAVID S. BROOKSHIRE, ANTHONY C. FISHER, ALLEN V. KNEESE, CHARLES D. KOLSTAD, DAVID SCROGIN, V. KERRY SMITH, MICHAELWARD and JAMES WILEN (1998), "Research Trends and Opportunities in Environmental and Natural Resource Economics", *Environmental and Resource Economics* 11(34): 383–397, 1998.

DE GROOT Rudolf S, WILSON Matthew A., BOUMANS Roelof M.J. (2002), "A typology for the classification, description and valuation of ecosystem functions, goods and services", *Ecological Economics*, pp.393-408.

DOSI Cesare (2000), "Environmental values, valuation methods and natural disaster damage assessment", Working material, ECLAC United Nations.

EHRLICH Paul R. and EHRLICH Anne H. (1992), "The value of biodiversity", *Ambio*, Vol. 21, N.3, pp.219-226.

EMERTON Lucy (2005), "Counting ecosystems as part of development infrastructure: using economics valuation to promote freshwater biodiversity conservation in Africa", Symposium 2005, American Museum of Natural History and the Center for Biodiversity and Conservation, "New currents in conserving freshwater systems".

ESTLE Sara J., COHEN Leonard, MYERSON Joel and HOLT Daniel D. (2007), "Discounting of Monetary and Directly Consumable Rewards", *Psychological Science*, Vol.18, N.1, pp.58-63.

FISKE Alan Page and TETLOCK Philip E. (1997), "Taboo trade-offs: reactions to transactions that transgress the spheres of justice", *Political Psychology*, Vol.18, N.2.

FRANKEL Herbert S. (1977), "Money: two philosophies. The conflict of trust and authority", Basil Blackwell.

GARROD Guy et Kenneth G. WILLIS (1999), Economic Valuation of the Environment: Methods and Case Studies, Edward Elgard.

GODARD Olivier (2005), « Les conditions d'une gestion économique de la biodiversité -
Un parallèle avec le changement climatique », Ecole Polytechnique, CNRS, Cahier n° 2005-018.

GOLLIER Christian (2002), "Quel taux d'actualisation pour le long terme?", *Revue d'Economie Financière*, N.66, pp.253-267.

GOLLIER Christian and WEITZMAN Martin L. (2010), "How should the distant future be discounted when discount rates are uncertain?", *Economics Letters*, N.107, pp.350-353.

GOWAN Charles, STEPHENSON Kurt and SHABMAN Stephenson (2006), "The role of ecosystem valuation in environmental decision making: Hydropower relicensing and dam removal on the Elwha River", *Ecological Economics*, N.56, pp.508–523.

HARDELIN Julien, KATOSSKY Arthur et MARICAL François (2010), « Pourquoi et comment monétariser l'environnement? », in « Donner une valeur à l'environnement : la monétarisation, un exercice délicat mais nécessaire », La Revue du CGDD (Commissariat Générale au Développement Durable), Décembre 2010.

HEAL Geoffrey (2004), "Economics of biodiversity, an introduction", *Resource and Energy Economics* 26, pp. 105-114.

HEAL Geoffrey (2000), « Valuing Ecosystem Services », *Ecosystems*, pp.24–30.

HEZRI Adnan A. and Stephen R. DOVERS (2006), "Sustainability indicators, policy and governance: issues for ecological economics", *Ecological Economics* 60, pp. 86-99.

INGHAM Geoffrey (1996), « Money is a social relation », *Review of Social Economy*, Vol.LIV, N°4.

KASSAR Ilhem and LASSERRE Pierre (2004), "Species preservation and biodiversity value: a real options approach, *Journal of Environmental Economics and Management*, N.48, pp. 857–879.

KOSOY Nicolas and CORBERA Esteve (2010), « Payments for ecosystem services as commodity fetishism », *Ecological Economics*, Vol.69, Iss.6., pp. 1228-1236

LAFFITTE Pierre and Claude SAUNIER (déc. 2007), « Les apports de la science et de la technologie au développement durable », Rapport à l'Office parlementaire d'évaluation des choix scientifiques et technologiques, Tome II : « La biodiversité : l'autre choc ? L'autre chance ? », Doc. Assemblée Nationale N. 501 et Doc. Sénat n° 131.

LEA Stephen E.G. and WEBLEY Paul (2006), « Money as tool, money as drug: the biological psychology of a strong incentive", *Behavioral and Brain Sciences*, N.29, pp.161-209.

LEDOUX L. and R.K. TURNER (2002), "Valuing ocean and coastal resources: a review of practical examples and issues for further action", *Ocean & Coastal Management*, N.45, pp.583-616.

LENTON Timothy M., HELD Hermann, KRIEGLER Elmar, HALL Jim W., LUCHT Wolfgang, RAHMSTORG Stefan and SCHELLNHUBER Hans Joachim (2008), « Tipping elements in the Earth's climate system", *PNAS*, Vol.105, N.6, pp.1786-1793.

LUDWIG Donald (2000), "Limitations of economic valuation of ecosystems", *Ecosystems*, N.3, pp.31-35.

MARIS Virginie and Jean-Pierre REVÉRET (2009), « Les limites de l'évaluation économique de la biodiversité», *Les ateliers de l'éthique*, Vol.4, No.1, la Revue du CREUM.

MEA (MILLENIUM ECOSYSTEM ASSESSMENT) (2005), Ecosystems and Human Well-being, Synthesis, Island Press, Washington DC, 137 p.

MEADOWS Donella (September 1998), "Indicators and Information Systems for Sustainable Development", A Report to the Balaton Group, 78p.

MEEDDAT (Ministère de l'Écologie, de l'Énergie, du Développement Durable et de l'Aménagement du Territoire) (2007), « Stratégie Nationale pour la Biodiversité : Rapport d'activité 2007 », 86p.

MEINARD Yves and GRILL Philippe (2011), "The economic valuation of biodiversity as an abstract good", *Ecological Economics*, Vol.70, Iss.10, pp.1707-1714.

MENDONCA M.J.C., A. SACHSIDA, P.R.A. LOUREIRO (2003), "A study on the valuing of biodiversity: the case of three endangered species in Brazil", *Ecological Economics*, N°46, pp.9-18.

MEYERHOFF Jürgen and DEHNHARDT Alexandra (2007), "The European water framework directive and economic valuation of wetlands: the restoration of floodplains along the River Elbe", *European Environment*, N.17, pp.18-36.

MURAYAMA Kou, MATSUMOTO Madoka, IZUMA Keise and MATSUMOTO Kenji (2010), « The neural basis of the undermining effect of monetary reward on intrinsic motivation », *PNAS*, Vol.107, N.49, pp.20911-20916.

NUNES Paulo A.L.D. et VAN DEN BERGH Jeroen C.J.M. (2001), "Economic valuation of biodiversity: sense or nonsense?", *Ecological Economics*, No.39, pp. 203–222.

OECD (Organisation for Economic Co-operation and Development) (1993), "OECD core set of indicators for environmental performance reviews", *OECD Environment Monograph*, N°83, Paris, France.

PEARCE David, ATKINSON Gilles and MOURATO Susana (2006), « Cost-Benefit Analysis and the Environment : recent developments», OECE Ed., 351p.

PEARCE David W. (2007), « Do we really care about biodiversity? », *Environmental and Resource Economics*, Vol.37, Issue 1, pp.313-333.

PEARCE David and MORAN Dominic (1994), The economic value of biodiversity, IUCN-The World Conservation Union, Ed. Eathscan, 172p.

PEARCE David W. and TURNER Kerry R. (1990), Economics of natural resources and the environment, Harvester Wheatsheaf.

PLATER et al. (2004), Environmental law and policy: Nature, law, and Society. Third Edition, Aspen publishers.

RISHER Peter and MARKOW Dana (1998), "Biodiversity in the Next Millennium", poll conducted for the American Museum of Natural History by Louis Harris and Associates.

RONNBACK Patrick et al. (2007), "Stockholm Ecosystem Goods and Services from Swedish Coastal Habitats: Identification, Valuation, and Implications of Ecosystem Shifts", *Ambio*, Vol.36, Iss.7, pp. 534-44.

SALLES Jean-Michel (2010), "Évaluer la biodiversité et les services liés aux écosystèmes : pour quoi faire ?" Académie des sciences, 9 février 2010, Conférence-débat "La biodiversité face aux activités humaines", http://www.academie-sciences.fr/video/v090210.htm

SALLES Jean-Michel and PUJOL Jean-Luc (2010), « L'évaluation économique de la biodiversité et des services éco-systémiques pour les décisions publiques : que retenir du Rapport Chevassus ? », Conférence IDDRI du 25 mai 2010, Paris, http://www.iddri.org/Activites/Seminaires-reguliers/Seminaire-Developpement-durable-et-economie-de-l%27environnement/L%27evaluation-economique-de-la-biodiversite-et-des-services-ecosystemiques-pour-les-decisions-publiques-que-retenir-du-Rapport-Chevassus

SCBD (Secretariat of the Convention on Biological Diversity) (2010), "Global Biodiversity Outlook 3", Montréal, 94 pages.

SCHERRER Sylvie (2004), Comment évaluer les biens et services environnementaux ? *La documentation française*, Réponses environnement, 48p.

SICARD Didier (2009), L'éthique médicale et la bioéthique (2ème éd.), Presses Universitaires de France, Que sais-je ?, 128p.

SIMPSON David R., SEDJO Roger A. and REID John W. (1996), "Valuing biodiversity for use in pharmaceutical research", *The Journal of Political Economy*, Vol.104, N.1, pp.163-185.

SPASH Clive L. and HANLEY Nick (1995), "Methodological and Ideological Options Preferences, information and biodiversity preservation", *Ecological Economics*, 12, pp.191-208.

SPASH Clive (2002), "Informing and forming preferences in environmental valuation: coral reef biodiversity", *Journal of Economic Psychology*, N.23, pp.665-687.

TEEB (2010), The Economics of Ecosystems and Biodiversity: Ecological and Economics Foundations, Ed. Pushpam KUMAR, Earthscan, London and Washington.

THOMPSON John D. (2010), "La nature sort de sa réserve : le rôle des espaces non-protégés dans la conservation de la biodiversité", Académie des sciences, 9 février 2010, Conférence-débat "La biodiversité face aux activités humaines", http://www.academie-sciences.fr/video/v090210.htm

VATN Arild and BROMLEY Daniel W. (1994), "Choices without prices without apologies", *Journal of Environmental Economics and Management*, N.26, pp.129-148.

VIVERET Patrick (2010), Reconsidérer la richesse, Ed. l'aube poche

WEGNER Giulia and PASCUAL Unai (2011), « Cost-benefit analysis in the context of ecosystem services for human well-being: A multidisciplinary critique", *Global Environmental Change*, No.838.

WEITZMAN Martin L, (1998), "The Noah's ark problem", *Econometrica*, Vol.66, N.6, pp.1270-1298.

ZELIZER Viviana (1989), "The Social Meaning of Money: "Special Monies"", *American Journal of Sociology*, Vol. 95, No. 2, pp. 342-377.

ESSAY 2. Monetary Valuations of Biodiversity: An Anthropocentric and Instrumental Approach?

Abstract

Drawing elements from a brief historical perspective on economics' definitions and from environmental ethics literature, this article discusses the anthropocentrism and instrumentality of economics and of biodiversity monetary valuations. It is suggested that the economic approach to the biodiversity can be weakly anthropocentric and instrumental, or rather strongly anthropocentric and merely instrumental, depending on the humans values it integrates and the valuations methods it uses. We conclude that a risk exists of making the economic approach strongly anthropocentric and merely instrumental when having recourse to monetary valuations of biodiversity, which prevent potentially this approach from fully being able to deal with existence and non-use values.

2.1. Introduction

Monetary valuations of biodiversity have the potential to help public decision makers understanding and managing our impacts on biodiversity. However, disagreements exist about the relevance and the boundaries of those roles. As tools evaluating the *monetary value* of some dimensions of biodiversity, monetary valuations are expected to support practical instrumental rationality in the development of public decisions and actions. They are especially expected to help developing means (budgetary efforts) in concordance with ends and to optimally allocate resources. However, they are also expected to be informative tools, capable of sensitizing and convincing about biodiversity's economic importance. Because those instrumental and informative roles simultaneously exist in public decision making, we can expect those two roles to interplay and valuations to also play a role in the earlier stage of

public decisions, which consists in identifying, selecting and weighting the ultimate goals and values of public actions (Picavet, 2011)[60].

If that is the case, then the theoretical foundations of monetary valuations and the worldview they rely on have to be clear and transparent for their user. It seems obvious to say that the economic worldview itself is partial (it has to be in order to be different from other disciplines), and that valuations are partial as well, but the work of some authors such as Méda (1999) underlines the fact that is has become less obvious. Confusion can exist today between economic notions and common language notions, which bring the risk of reducing the latter notions to the first. Economic utility may be confused with social utility and economic value and with value. Méda (1999) suggests that such a confusion result from last developments in economics; we will provide in the first section a brief historical perspective on the evolution of economics as a science and see that since the 1960s, economics has become more and more an approach and less a subject-matter science. Its approach to the world has been narrowly specified while its subject-matters have been broadened. This may give a feeling that economics can deal with everything, and ultimately provide to economics the pervasive capacity to introduce in society some confusion between, complex and multidimensional notions (such as wealth and welfare), and the restrictive understandings that those notions have acquired in neoclassic economics (Méda, 1999) . It seems therefore relevant to underline some fundamentals assumptions of the economic approach, in order to better characterize the realities and values of biodiversity that monetary valuations cover and do not cover.

This article will only focus on some dimensions of economics' - and therefore monetary valuations'- ethical foundations, mainly their anthropocentrism and instrumentality. There are however many more dimensions of the economic theory and of monetary valuations that should be studied to do that, among them the conceptual representation of value in economics, the conceptual representation of biodiversity in economics, and the fundamental principles and assumptions built-in the different valuation methods. While the flourishing literature on biodiversity valuations often deals with the different types of values that biodiversity has, and the different types of values that valuations methods can estimate, it is rarer to find some justifications of the fact that those methods can and do indeed measure those values. We will

[60] Valuations used in CBA can be used to debate about the desirability of some public objectives with the efficiency criteria (Pearce et al, 2006).

see that asking the question of the anthropocentrism and the instrumentality of the economic approach to biodiversity will help us to discuss this particular point. Depending on the human values it integrates and the valuations methods it uses, an economic study can be strongly anthropocentric and merely instrumental or rather weakly anthropocentric and instrumental.

2.2. A brief historical perspective on economics' definitions

Etymologically, economics derives from the Greek "oikonomos" composed of the roots "oikos" referring to the house and "nomos" referring to the rules, the administration. Invented by Xenophon in the fourth century BCE, the term economics first referred to the art of running/administering/leading/managing a house/household (Rey, 2006; Backhouse and Medema, 2009). The domestic character of those human actions refers, as Godard (2005) suggests it, to the symbolic representation we have of human societies as family, rooted in a territory and part of a lineage. As a discipline and a science – economics is an academic science since the 1880s (Blaug, 1996) -, economics was then understood and defined quite differently depending on the era. Economists developed different approaches to what was legitimate to study and to what was the appropriate method for it (Backhouse and Medema, 2009). Schematically, in the Middle-Ages, economics is conceived as a normative reasoning, consisting in prescribing good and desirable management rules; morality is dominating in this approach (Samuelson, 1997). In the Renaissance, a time when growing authority of European monarchs depends on material wealth, economics becomes the science of wealth (Samuelson, 1997). Morality has not disappeared yet in the work of Smith, who conceives economics as one facet of a larger system of moral philosophy (Backhouse and Medema, 2009), but it tends to be eluded by other classic economists such as Say and Ricardo, who want to create a new and separate science (Samuelson, 1997). Wealth per se is also apprehended differently: wealth can include only material wealth (A. Smith) or also include services and social wealth (J.B. Say). In this last case, economics could cover a very broad range of issues (Backhouse and Medema, 2009) and the uneasiness of defining strict boundaries for what economics and wealth are, leads thinkers to look for a more abstract and constraining definition of economics (Samuelson, 1997). Methodological approaches to economics emerged (J.S. Mill for instance), as well as definitions based on other objects than wealth such as exchanges and prices, and based on other focuses than nation's production, consumption and accumulation of wealth such as the individual behavior (Backhouse and Medema, 2009; Samuelson, 1997).

This move towards individualism led to the marginal revolution (starting in 1870s) and the exploration and formalization of individual behavior. The particular art of non-wastefulness in the administration of resources (Wicksteed, 1910 and Wicksell 1934) became a focus, along with two notions explicative of human behavior, utility and rationality (Backhouse and Medema, 2009). In addition, famous Robbins (1932)'s definition of economics based on scarcity[61] slowly got acceptance and even wide acceptance in 1960s (Backhouse and Medema, 2009). By the 1960s, definitions of economics mixed scarcity and the choices that it necessarily implies to make. Economics is seen as the science of choices under scarcity. Depending on the authors, this particular choice process is driven by individual behavior being either rational, or maximizing, or rational and maximizing. The omnipresence of scarcity and of its resulting opportunity costs led this approach to draw "no limitations on the subject-matters of economics" (Robbins, 1932). Economics became more an approach than a subject matter (Backhouse and Medema, 2009). Since 1960s, a strong movement in economics has been narrowing its approach and broadening its subject-matters (Backhouse and Medema, 2009), making of it the science of the efficient resources allocation (Blaug, 1996) or the science of gains (of utility) maximization under constraints of resources scarcity. However, no unanimity exists about those definitions (Backhouse and Medema, 2009); there are still economists defining economics by its subjects such as Buchanan and Coase; and others working on the psychological and sociological validity of economic formalization of human behavior (Backhouse and Medema, 2009).

Therefore, adhering to a specific definition of economics in this article, be it neoclassic or not, would constrain the scope of economics (Backhouse and Medema, 2009), which is not our goal here because we are tried to get the essence of the economic approach. This is why we will not do it and we will rather refer to several well-used definitions and key words of economics, in order to test later its anthropocentrism and instrumentality. If at least one word suggests that economics is not anthropocentric or instrumental, then we cannot conclude entirely, but we will see that it is not the case. We rely for this on Backhouse and Medema (2009)'s review of definitions of economics (in Annex), from which we extract key words employed to describe economics, which we classify as follows: words describing the dimensions of human actions that concern economics, and words describing objects and

[61] "Science which studies human behavior as a relationship between ends and scarce means which have alternatives uses" (Backhouse and Medema, 2009).

actors involved in those actions, and/or objects and actors generally studied by economics (table 1).

Figure 14: Key words describing the subject-matter of economics

Dimensions of human actions	Dimensions of human actions (continuation)	Objects	Actors
To administrate (0, 13, 14, 19)	The practical activity of economizing (10)	Scarcity/ scarce resources (3, 4, 19, 20, 22)/ scarce means (15, 21) or resources (13, 14)	Human beings (2)/ people (6, 20)/ men (17)
To manage (0,3)	The ordinary business of life (12) / of getting of living (17)	Ends (15) / alternative (21) or competing (22) ends	Individuals (1, 4, 12, 14)
To solve (21)	The elimination of waste in administration of resources (13, 14)	Resource allocation (20)	Persons and groups in society (20)
To choose (4, 20) / the decision-making process (5)	Dealing with the relationships between ends and means (15)	Wealth (16) and it production (8), consumption and distribution (7) / relative national fortunes (6)	Households (0, 14)
To allocate (22)	Complex human practices and relationships (17)	Various commodities (20)	Businesses (4, 14)
To coordinate (2)	The Human behavior (5, 15)	Costs and benefits (20)	Society (2, 3, 4, 12, 20, 21)
To cope with (4)	Ways humans organize themselves for their provisioning (25)	Utility / Pleasure and pain (11)	Government (4) / Sovereign (6)
Policies (enriching people or the sovereign) (6)		Wants/desires (2) / unlimited wants (19)/ Preferences (23)	State (14), Nations
To exchange (9) / exchange relationships (24)		Well-being or welfare / material requisites of well-being (12)	Mankind (8, 12), Man (16)
To use (19, 20) / alternative uses (15, 20)		Money	
To produce and distribute (various commodities) (20)		Market equilibrium (23)	
Wealth-getting and wealth-using activities (16)/		Industry (17)	

Combined operations (for production of wealth) (8)			

Sources: (0) Etymology; Backhouse and Medema (2009) for (1) Krugman and Wells (2004), (2) Colander, 2006a, (3) Mankiw (2001), (4) Bade and Parkin (2002), (5) Gwartney, Stroup, Sobel, and MacPherson (2006), (6) Smith (1776), (7) Say (1803), (8) Mill (1844), (9) Richard Whately (1832), (10) Carl Menger (1871), (11) Jevons (1871), (12) Marshall (1890), (13) Wicksell (1901), (14) Wicksteed (1910), (15) Robbins (1932), (16) Ely, Adams, Lorenz, and Young (1926), (17) Slichter (1931), (18) Parsons (1937) and Spengler (1948), (19) Campbell McConnell's (1960), (20) Samuelson and Temin (1976), (21) Friedman (1962), (22) Stigler (1942), (23) Becker (1976), (24) Buchanan (1964); (25) Bromley (2006) for whom all human behaviors and actions of interest for economics are humans' organization for their provisioning.

This key words presentation of economics favors an understanding of economics based on its subject-matter, even though we saw that economics can also be considered as an approach. Therefore, table 2 provides us with some key words not yet mentioned in table 1 and that are used for describing economics as an approach. Some of them actually describe dimensions of human actions, but their attempt to categorize human behaviors in one way also makes them describers of economics as an approach to human behavior. For instance, claiming that economics studies the rationality of human behavior is also claiming that economics is about rationality and stands as the science of rational human behavior.

Figure 15: Key words describing economics as an approach

Economics studies…	**Economics as a … approach**
The rationality (18) of behaviors	Rational
Maximizing (18, 19, 23) behaviors / maximizing the attainment of the ends (22)	Maximizing
The principles (14, 22) or laws of human actions	Objectivistic and laws revealing
Calculus (of pleasure and pain) (11)	Quantitative

Sources: Backhouse and Medema (2009): (11) Jevons (1871), (14) Wicksteed (1910), (18) Parsons (1937) and Spengler (1948), (19) Campbell McConnell's (1960), (22) Stigler (1942), (23) Becker (1976).

Now, before referring further more to those tables and discuss the ethical positioning of economics, we need to introduce the notions of anthropocentrism and instrumental approach.

2.3. Anthropocentrism and instrumental approach

In ethics, a common distinction exists between moral patients and moral agents. Moral patients are the entities whose welfare interests we have to consider because they are have the right to moral standing (Baggini and Fosl, 2007), while moral agents are the entities actually morally responsible for their actions (Maris, 2010; Baggini and Fosl, 2007) because they have control over those actions and judgmental capacities (Baggini and Fosl, 2007). Thanks to those two categories, a center (or reference point) of moral judgment can be identified and referred to when asking the questions "Who judges?" or "Who is to matter morally?" This center makes explicit the boundaries of the moral community, composed of moral patients and agents, and it can be used to differentiate different ethics.

Another distinction in ethics exists between intrinsic value and instrumental value. Schematically at this point, we can understand the intrinsic value [definition 1] as the value that some beings have for their own sake and not from being useful to their external environment, while the instrumental value refers to the value beings derive from being useful to their external environment. A link is often made in the environmental literature between the notions of moral agents/patients and intrinsic value/instrumental value. Being a moral subject, and a fortiori a moral agent, would imply having more than an instrumental value and it may even imply having some intrinsic value. However, one of the main disagreements existing between the different environmental ethics currents deals precisely with the kind of criteria that can be relied upon to identify moral agents from moral subjects, and the moral community from the rest. Not all ethical approaches rely on the concepts of instrumental and intrinsic values to define the moral community. Schematically, in the case of pathocentrism (utilitarianism extended to other sentient individuals) (Chadwick and Schroeder, 2002), all beings capable of suffering/feeling pain are moral subjects; in the case of biocentrism, all beings alive are moral subjects and in the case of ecocentrism, moral subjects are biotic communities. However, the intrinsic value can be brought back as criteria by considering that those criteria just listed grant the status of moral patient to some entities because they grant them some intrinsic value. Anthropocentrism is then often resumed as an ethical approach that grants intrinsic value only to humans, because humans benefit from an intellectual and moral superiority over other living entities (auto-reflectiveness, self-consciousness, willingness, deliberation). Morality would be the distinct and important part of human life (Becker and

Becker, 1992), entitling humans to dominate and use other beings and to be the only moral subject and object. Three major conceptual steps will lead us to moderate this definition of anthropocentrism. First, the introduction of two branches of anthropocentrism: the Strong Anthropocentrism (SA) and the Weak Anthropocentrism (WA); second, the introduction of different definitions for the intrinsic value and for the instrumental value and approach, and third, the introduction of Norton (2003)'s approach to WA and SA.

For WA, humans are more valuable than other entities but those entities (including nature) may have some intrinsic value (Barrett and Grizzle, 1999) and be moral subjects, at the periphery of the main moral center where humans stand. Where SA cares exclusively about the satisfaction of human interests and the instrumental values non-human beings have for humans, WA cares about some non-human interests as well. Where SA emphasizes the domination of humans on nature and other beings (Barrett and Grizzle, 1999), WA considers that humans are part of the ecosystem. This distinction between WA and SA is not always as clear as we suggest it here however, as the following quotations from Clifton (2010) shows it. WA is defined as the ethics for which "human interests, for the *most* part, take precedence over non-human life" and "where non-human life is *mostly* considered in terms of its instrumental value to humans", but it is also said that the instrumental use of non-human things is the *only* value those things have for WA, transforming WA in SA if we stick to our definitions. Then, other differences in the apprehension of anthropocentrism exist, which result from the concomitant existence of different definitions of the intrinsic value and of the instrumental value and approach.

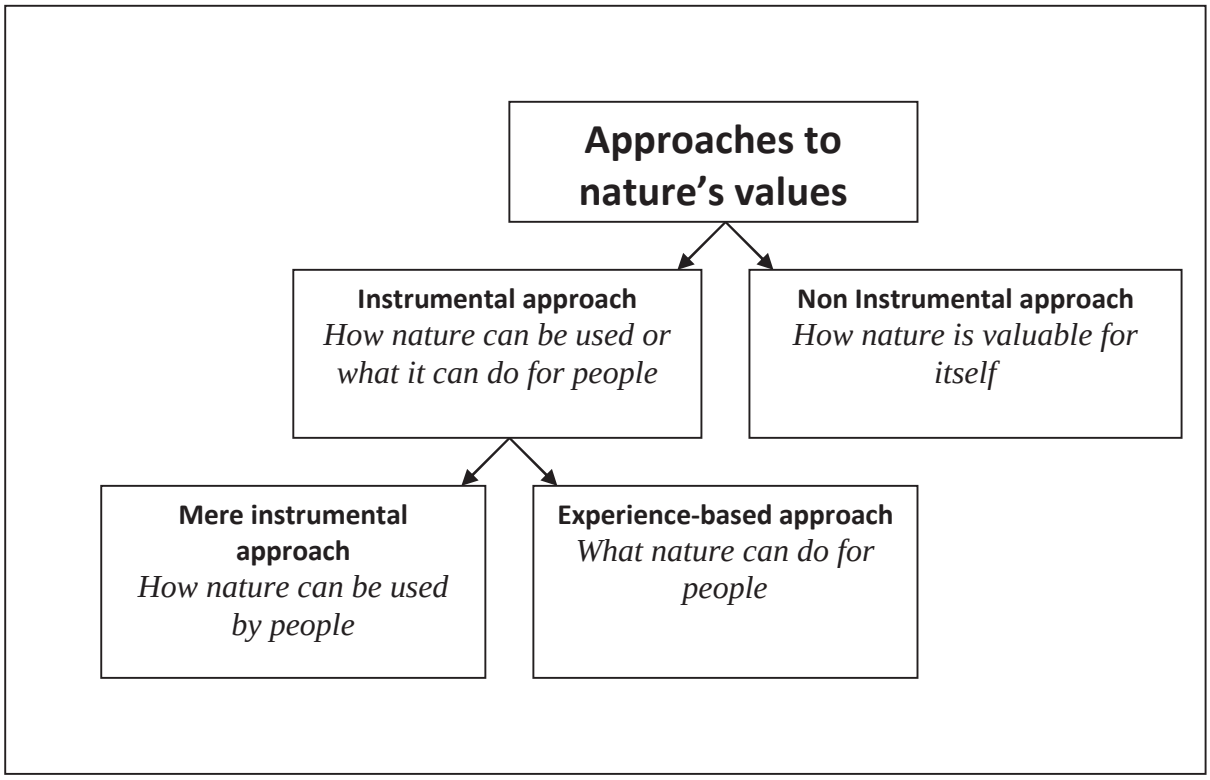
A common definition of an instrumental approach in the literature is an approach that values an object as intermediary to reach a goal and not as an end in itself (Maris, 2010). As a result, the instrumental value of an object is assessed in terms of how this object can be used and what it can do for people (Baggini and Fosl, 2007). A non-instrumental approach is therefore an approach that considers an object as an end in itself, as an object that has some value whether it serves/is used or not, i.e. that has an intrinsic value as defined by [definition 1]. Non instrumental value and intrinsic value refer here to the same notion of value and that instrumental and non-instrumental approaches could be complementary, i.e. that attributing some instrumental value to an object may not prevent humans from also attributing some intrinsic value to it and ultimately consider it as a legitimate moral patient.

This distinction between instrumental and non-instrumental approaches seems however insufficient to represent all approaches to biodiversity values. In the Ecosystem Services Approach (ESA) literature for instance, humans are assumed not only to value ecosystems' provisioning, regulating and supporting services, but also to value the spiritual, recreational, aesthetic or educational dimensions of ecosystems. Those latter dimensions are understood as dimensions of the ecosystems revealed through human experiences with nature, like the scientific study of nature, or the aesthetic appreciation of nature while the practice of artistic or physical activities as walking, climbing, sailing (Benson, 2000). Experiences refer to a thing or a situation that is personally lived through or encountered by individuals, and which will influence the way those individuals think and behave[62]. They can also be formed via contemplative gazes, disinterested attention and selfless absorption in nature (Benson, 2000). "Because, the longest period of human evolution took place within the context of undomesticated habitat, the workings of the human brain for gathering information and a sense of well-being are very strongly tied to the experience of natural landscapes and species diversity" (Gallagher, 1995[63]; in De Groot et al., 2002). When humans experience rather than strictly use nature, they do not employ or put into service nature for some uses but rather come to it with some purposes and without necessarily foreseeing the nature or the intensity of the utility they can derive from it. This is where we would like to introduce a distinction between two branches of the instrumental approach, one that could be called the "mere instrumental approach", that only addresses humans' uses of nature, and the "experience-based approach" that focuses on the influence of nature on humans (see the previous definition of the instrumental value by Baggini and Fosl (2007)).

[62] Webster (1997), Oxford (2000).

[63] Gallagher W. (1995), The Power of Place: How Our Surroundings Shape Our Thoughts, Emotions, and Actions, Poseidon Press, New York.

Figure 16: Approaches to nature's value[64]



For some authors, it is only in experiences of things that values, including the intrinsic value, reveal themselves either to our thinking or to our feeling (Benson, 2000), and allow us to then develop different approaches to nature's value. At this stage, we still need to further discuss the essence of the intrinsic value. Indeed, we are left so far with definitions of non-instrumental and intrinsic value that are identical. Though, the intrinsic value can actually be defined at least in three different ways (O'Neill, 2003).

"The term 'intrinsic value' has a variety of senses and many arguments on environmental ethics suffer from a conflation of these different senses", (…) "in much of the literature on environmental ethics the different senses of 'intrinsic values' are used interchangeably" (O'Neill, 2003).

Beside [definition 1], the intrinsic value can also be defined as [definition 2] the value that something has independently of the valuation of valuators. This definition defines the intrinsic value by the process of emergence and revelation of the intrinsic value. Finally, it can be defined as [definition 3] the value that an object has solely in virtue of its intrinsic/non-

[64] This is a personal representation of existing approaches to nature's values, not a well-know and accepted representation.

relational properties (O'Neill, 2003). O'Neill (2003)' illustrates how confusion between one another definition exists. Confusing [definition 1] and [definition 2] leads for instance to find equivalent the statements "natural patterns do not have value independent of the evaluations of humans" and the statement "natural patterns have only instrumental value". This is confusing the author of the object's valuation (humans) with the type of value addressed by the valuation. We can wish that rain forest exist after the disappearance of humankind, which proves that we can value future forests despite our lack of use of it. Then, confusing [definition 1] with [definition 3] can lead to claim that [definition 1] implies [definition 3] for instance. But an object might have value in virtue of its relation with human beings without thereby being of only instrumental value for humans: wilderness has value in virtue of human absence for instance. The first of those two confusions (confusing the source of the valuation with the type of value being valued) can lead any ethics relying on humans' valuations, among them anthropocentrism, to be reduced to instrumental approaches or even to mere instrumental approach.

In this context, other approaches no directly relying on the intrinsic value criteria to define anthropocentrism, may be helpful. Norton (2003) suggests for instance, that anthropocentrism be defined as the approach that considers only humans values. SA would be the approach that only cares about- and relies on- *felt preferences* for guiding decisions and WA would is the approach that allows for criticism of felt preferences and cares also about *considered preferences*. Both types of preferences refer to some desire or need of human individuals but considered preferences result from some judgment about those desires or needs, and their consistency with the rationally adopted world view of the valuator. Norton (2003) introduces reasons for WA world view to incorporate concerns for nature: (1) the recognition of the close relationships between humans and other living species/harmony with nature/appeal to improve human spirituality and (2) the importance of human experiences as basis for value formation (Norton, 2003). The fundamental point about this approach to anthropocentrism is that it is not constrained to only analyze 'mere instrumental values' and it does not require the questionable ontological commitment (Norton, 2003) of attributing an intrinsic value to nature for justifying nature's protection. A rational and spiritual process can lead to recognize the instrumental and experiences-related values of nature and to construct preferences and reasons to protect it, that still find their locus in human values (Norton, 2003). Human values, rather than humans themselves, are the center of reference for value judgments

in anthropocentrism. Norton (2003) understanding and promotion of the weak anthropocentrism ultimately supports an indirect duties theory toward other living beings, which supposes that we have indirect duties toward other living beings from our direct duties toward other human beings, god or ourselves (Becker and Becker, 1992). It also corresponds to Boddice's (2011) second reason for having recourse to anthropocentrism: the acknowledgment of human ontological boundaries.

Indeed, the recourse to anthropocentrism rather than to non-anthropocentrism can be explained by two reasons according to Boddice (2011). The first reason is "human chauvinism": the human belief or knowledge in his superiority over other living beings. It is one way to answer to the fundamental question of defining human beings by contrast with anything else in nature (Sax, in Boddice, 2011), which bases its rationale on the differences existing between humans and other beings regarding understanding, power, autonomy, guilt, virtue, wickedness, auto reflectiveness, self-consciousness, willingness and deliberation. It has been criticized of specism by the animal liberation movement (Canto-Sperber, 1996) and animal rights promoters who often chooses to rely on similarities rather than differences, between humans and other beings (life, sentience, some intelligence) (Regan, 2009a) to argue for equal moral standing for humans and animals. The second reason of anthropocentrism for Boddice (2011) is the acknowledgement of human ontological boundaries, the limitations of humans to think about objects without this thought being biased by their human condition. Even if we agreed that animals have complex social relationships (Hof and Van der Gucht, 2007) and are eusocial (Wilson, 2012), we would never be able to fully understand their complexity and to fully compare them to human societies. For instance, numerous studies about animal welfare exist (Broom and Johnson, 1993) and tend to assert that pain exist even in animals like fishes (Braithwaite, 2010), but those studies obviously have to rely on some interpretation of the signals send by the animals being studied (stress is an indicator of pain for instance, Broom and Johnson, 2010) that may be anthropomorphic because they are ultimately related to us (consciousness, sensitivity to pain) (Becker and Becker, 1992).

Figure 17: summary of the definitions of anthropocentrism

Anthropocentrism	
Strong Anthropocentrism	**Weak Anthropocentrism**
Definitions 1: relying on some criteria to identify humans as the only (SA) or the main (WE) moral patient. *This criterion can be intrinsic value.*	
Recognize only humans as moral patient. *Grants intrinsic value only to humans and grant therefore to non-human entities only instrumental value. Cares only about human interests.*	Recognize mainly humans as moral patient. *Grants more intrinsic value to humans (at the center) than to non-human entities (at the periphery) which have also instrumental value. Cares mainly about human interests but will also consider non-human interests.*
Definitions 2 of Norton (2003): anthropocentrism considers only humans values, no ontological commitment about the intrinsic value.	
Cares about- and relies on-felt preferences for guiding decisions	Allows for criticism of felt preferences and cares also about considered preferences (resulting from personal judgment and consistent with a chosen worldview of the valuator)

2.4. Anthropocentrism and instrumentality of economics

Economics, from what we can deduce from table 1, is a science that focuses on humans (see column actors) and their behaviors (5,15)[65] and actions, as individuals (1,4,12,14) or groups of individuals (0, 14, 20), within or without some organizations and institutions such as businesses (4,14) and government (4). Bromley (2006) suggests that the overall human behaviors and actions of interest for economics be humans' organization for their provisioning (25). Obviously, mankind (8,12)/ humans, are the center of reference for value judgments in all those definitions, and are implicitly the moral subject identified in economics. A non-human "economics" could be conceived, referring to the way non-human

[65] Numbers refers to the authors, quoted in the sources of table 1, providing a definition of economics mentioning those key words which are reviewed in table 1.

species organize their provisioning, but as a separate science, perhaps as a branch of ethology. Does this imply that only human value counts in economics, as in the anthropocentrism defined by Norton (2003)? We assume so, because all definitions reviewed here suggest so. Individuals and groups of individuals can claim to be ethically anthropocentric but they can also be pathocentric or biocentric. Human values are necessarily anthropogenic, they are dependent on some kind of anthropomorphism, but are not necessarily anthropocentric (Maris, 2011[66] ; Barrett and Grizzle, 1999). The vegetarian and vegan industries are good examples of industry (17) and markets (23) that produce and distribute some commodities (20) that respond to some non-SA concerns, especially concerns regarding the way humans exploit animals for resources. However, those ethical concerns be they WA, pathocentric or biocentric, do not make the scientific study of them and the industry responding to them a non-SA science or industry. Their existence motivates economics to study them and to take them into account. If humans have ethical preferences (23) for their way of organizing their provisioning (25) that influences the nature of a system of provisioning, economics will take them into account, but only for the reason that those values are anthropogenic (and not necessarily because they are themselves anthropocentric).

So indeed, economics is anthropocentric according the two definitions of anthropocentrism provided in table 4, because it takes only human values into account. Regarding Norton (2003)'s definition, non-human interests can be taken into account by the anthropocentric approach, but only indirectly, i.e. if humans happen to value them (it is called the indirect duty approach). It is therefore possible for economics to be WA or SA under Norton (2003)'s definition, as well as under the main first definition of anthropocentrism, humans may recognize other entities as moral patients and considers non-human interests. Only one situation - its plausibility is not discussed here- will oblige economics to be SA: if the criteria used to decide who is a moral patient, is the intrinsic value as defined in [definition 2]. Put another way, economics won't take into account situations in which some value is granted to non-human entities independently of any human valuator. So we suggest that economics is anthropocentric because it focuses on human values, but that it could be WA or SA. We now further assume that it will actually produce SA or WA studies and doctrines, depending on the nature of human values it is applied to (or based on). If citizens care about non-human entities, grant them the status of moral patient or even some intrinsic value (as defined under

[66] « Les valeurs morales des humains anthropogéniques, pas nécessairement anthropocentriques, et tributaires enfin d'une forme d'anthropomorphisme » (Maris, 2010).

definition 1 and 3), then economics taking those human values and preferences into account will probably produce an analysis that is not SA but rather WA.

This conclusion on the anthropocentrism of economics and the weak or strong anthropocentrism of its studies, underline the responsibility of economics for not neglecting the ethical concerns of citizens, and also for revealing the ethical implications of prevailing economic institutions as they may not comply with current citizens' preferences. Indeed, according to Bromley (2006), economics and the study of economic institutions do include the study of ethics, seen as one of the fundamental realms of human thought and action, and the one that deals with the rules of conduct arising from the inevitable conflict of interests, necessitated by scarcity, and enforced by the moral sanctions of collective opinion. This vision contradicts therefore the idea that economics exclusively studies and compares alternative ways to reach known goals. Economics is seen here as a science that must be concerned and transparent about ethics, ethical preferences of citizens and the ethical implications of prevailing and potential economic institutions.

Finally, is economic an instrumental approach? Because economics considers all human values but only human values, it won't try to analyze how nature is valuable by itself and it is therefore instrumental as defined in table 3. There is no reason however, why it should only be a mere instrumental approach, and the fact that part of the literature on monetary valuations of biodiversity attempts to value so-called 'non-instrumental value' supports this assumption.

2.5. Are biodiversity's monetary valuations merely instrumental and strongly anthropocentric?

A last discussion to lead here deals with the influence that valuing monetarily biodiversity can have on the nature of the economic approach of biodiversity. Does it make it become merely instrumental, i.e. caring only about how nature can be used by people rather than carrying about how nature can be used by people *and* about what it can do for people? Does it make it strongly anthropocentric, i.e. only recognize humans as moral patient

(definition 1), or only take into account only felt preferences and not considered preferences (definition 2)?

Monetary valuations of biodiversity are monetary evaluations of the value of some particular features of biodiversity such as its components (nature resources), its functioning systems (water cycle, carbon cycle), and its cultural and spiritual dimensions. Indeed, they are rarely about the importance of biodiversity per se (Beaumont et al., 2008; Nunes and Van Den Bergh, 2001; Pearce, 2007) and biodiversity refers to the diversity of the living and to the natural processes that occur within the system that living organisms constitute. Those organisms interact between themselves and with their changing environment (Ehrlich and Ehrlich, 1992), which creates not only a diversity of genes, species and ecosystems (three dimensions of diversity usually cited), but also a functioning system as a whole, which evolves and adapts to internal and external pressures. Biodiversity can therefore be seen as a property but also as a process (Maris, 2010), property and process each contributing to the maintenance of the other; or as a resource (OECD, 2001) but also as a potential provider of resources.

Therefore, monetary valuations of biodiversity cover a wide range of objects and values. Besides valuing goods usually monetarily valued in societies (such as natural resources), they are also aimed at valuing cultural, aesthetic, legacy, altruist or existence values (TEEB, 2010) of biodiversity. For the first category of objects just mentioned, i.e. those already having some own or related monetary value on markets, the process of monetarily valuing them consists in using and improving the accuracy of those existing values. For the second category of objects however, the process of monetary valuation actually introduces a shift in the conceptual approach to the value of the objects itself, by first attempting to estimate this value quantitatively, and second by attempting to value it monetarily.

The simplest way to monetarily value an object is to consider its price. For instance, wood varieties exist thanks to the functioning and the existence of biodiversity, and have market prices. One can assume that this price is a good proxy for a monetary value of woodsy/forest biodiversity. However, one can also suggest that prices, resulting from the imperfect confrontation of demand and supply, neglects some dimensions of woodsy biodiversity's value, not integrated in the price but otherwise valued by individuals such as

the cultural significance of particular type of wood for a society. And many valuation methods rely on existing prices or costs to estimate monetary values. The travel-cost method for instance, consists in valuing monetarily the recreational benefits procured by a non-priced recreation site (Garrod and Willis, 1999) to the individuals visiting this site. It does so by estimating the consumer surplus of visitors (Garrod and Willis, 1999), based on their costs of travelling to the site (including time, converted in monetary equivalent). The hedonic prices method deduce the value of an environmental quality from analyzing the variability of real-estate and land prices (Rousseau de Vetter, in Zuindeau, 2000) to which the environment is related (Markandya et al., 2001). The human capital method values the effect of an environmental attribute on human health by calculating the expenses that have to be spent to deal with the illness and the loss of earning resulting from humans being ill or dead and therefore working less time and less efficiently.

Figure 18: Common revealed-preferences monetary valuation methods

Travel Cost Method
Hedonic Prices and Hedonic Wages Method
Human Capital Method
Cost of Illness Method
Restoration and Replacement Costs Method
Preventative / Protection Expenditures Method
Mitigatory Expenditures Method
Averting Behavior Expenditures Method
Production Function Method
Change in Productivity Method

In all those revealed-preferences valuation methods, prices and costs are supposed to reveal essential information about the preferences/values attributed by individuals to objects. Technical improvements over decades have been realized to make them and their resulting estimated valuations more accurate. This has required settling the value of many objects, often by relying on a merely instrumental approach to them. In the travel cost approach for instance, the conversion of the time spent travelling to the site into monetary equivalent is problematic and controversial. Should this time be valued at as a leisure time or a lost time? The often adopted solution is to value this time as a lost time using the hourly rate of work income, which means reducing the whole experience of the travelling trip to the natural site to a uni-dimensional unproductive and valueless time. It is a merely instrumental solution. Also, the travel cost approach only considers individuals actually visiting the site for establishing its

value (Scherrer, 2004), which neglects those not visiting the site even though they may value it and derive from it some benefits. Such an approach leaves no space for what nature can do for those people and it tends again to be merely instrumental. However, those methods are not systematically and/or completely merely instrumental. Considering the time spent travelling to a site as an indication of what people are willing to do/pay for visiting this site seems relevant and leaves room for interpreting the nature of their motivation and of the benefits they derive from their trip. The translation in monetary terms of this time however, brings a restrictive interpretation of the meaning and the value of this time.

So, even for objects already being related to some monetary value and a fortiori for the other, it is possible that monetary valuations change the meaning of - and transform - products, relationships, and emotions into an abstract and seemingly objective numerical equivalent. In doing so, it may result in incomplete, imperfect, oversimplified or simply wrong illustration of the reality. Kosoy and Corbera (2010) or Bromley (2006) denounce for instance the commoditization of things that results from such a process, and researchers on alternative national wealth indicator to GDP condemn the valuations of all activities creating monetary flows without considering the nature of those activities (Viveret, 2010). Experiences with nature may lose some of their meaning, and what nature can do for people may be overlooked and overruled by how nature can be used by people. Also, money provides and signals power which may even more emphasize uses of nature by man. Thus, a real and significant risk exists to make the economic approach a mere instrumental approach by establishing and relying on monetary valuations.

As for the anthropocentrism of monetary valuations, money reflects but also affects the ever-changing relationships between individuals and the society which they compose (Frankel, 1977). Monetary measures and ratios, the basis of market pricing relationships, can be considered by individuals (Fiske and Tetlock, 1997) to undercut, degrade, corrupt, or repudiate the self-images and social identities as moral beings of those using them for relational models other than market pricing; and to subvert, undermine, deprave, and jeopardize the real value of those models and the social order. They may also contribute to the evolution of societies toward a more individualistic model (Frankel, 1977), risk to turn public judgment into selfish individual judgment (Plater and al., 2004), and strengthen the power of money as a domination tool. For all those reasons, monetary valuations tend to make the

economic approach strongly anthropocentric, as described by definition 1 (humans are the only patient). We will see that this risks remains under definition 2.

As already mentioned, market pricing language can be rejected by individuals when applied to the three other types of relationships such as communal sharing, authority ranking or equality matching relationships (Fiske and Tetlock, 1997). This suggests that ethical trade-offs cannot be solved with money and that monetary valuations should not be created before those trade-offs are solved. Moreover, this implies that the ethical commitments of valuations methods should be known and accepted or rejected before we recourse to them. Under definition 2 of anthropocentrism (Norton, 2003), it is assumed that only humans values counts but also that in the case of weak anthropocentrism, those values results from two types of preferences, the felt preferences and the considered preferences. And the considered preferences result from some judgment about those desires or needs, and about their consistency with the rationally adopted world view of the valuator (Norton, 2003). So only when ethical matters are indeed addressed upstream or simultaneously with the elaboration of monetary valuations can the economics approach remain weakly anthropocentric. We can illustrate how certain methods of monetary valuations at least prevent economics from remaining weakly anthropocentric with the example of the Contingent Valuation Method (CVM).

The CVM is by far the most used method (Nunes and Van den Bergh, 2001), but it is a controversial (OCDE, 2001) stated-preferences valuation method, which values biodiversity by eliciting either individuals' willingness-to-pay for an expected improvement in the quantity or quality of some environmental goods (resulting from the implementation of a policy or project), or individuals' willingness-to-accept a compensation for deterioration in environmental provision (Markandya et al., 2001). Surveyed individuals are informed about biodiversity and introduced to hypothetical scenarios of project/policies or event that are respectively expected to improve (1) or deteriorate (2) the environment; and they have to elicit the monetary amounts that they would actually accept to pay (1) or to receive (2) if those scenarios were to happen and that they were to pay or receive those amounts. Those monetized values responses to hypothetical choice situations (Vatn et Bromley, 1994), are assumed to resume and reveal the economic value of a change in biodiversity for those individuals. However, it is difficult to provide adequate information for individuals to state

their value (Arrow et al., 1993). Individuals have limited knowledge about biodiversity (Ludwig, 2000; Bullock et al., 2008) and limited ability to internalize and proceed from the information given (Arrow et al., 1993; Allen and Loomis, 2006) ; the time they dispose to think about the questions is often too short (Bishop and Heberlein, 1979). Therefore, they may not be able to judge rationally their desires and needs and ultimately form accurate *considered preferences*. And indications of the fact that CVM produces *felt preferences* exist. What we would do and therefore can state in a CVM study differs from what we do (Bishop and Heberlein, 1979). Individuals have been observed signaling non-economic considerations by bidding ('warm glow effect', Arrow et al., 1993) because they derive moral satisfaction from it, and observed bidding different monetary amount for things taken separately and for their sum ('embedding effect'; Scherrer, 2004; Arrow et al., 1993). Those responses may partially exist because of a lack of time devoted to the formation of *considered preferences*. This is an example of method valuation that can make the economic approach strongly anthropocentric by neglecting considered preferences.

2.6. Illustration

We can now illustrate, more generally, how strong hypothesis used in economics exist about individuals' behaviors, biodiversity and biodiversity's valuations and can lead the economic analysis of biodiversity to be strongly ethically loaded and limited in its capacity to deal with biodiversity as long as technical improvements are made without major conceptual improvements about the nature of the object studied.

2.6.1. Static optimization model

We consider C the consumption of private goods and B the enjoyment of biodiversity, both providing utility to individuals. We are in a competitive environment, in which private goods are consumed at a price p_1 and biodiversity is enjoyed at a price p_2. I represents Income, U represents Utility. The program of maximization for the social planer is therefore

$$(S1)\ \begin{cases} \underset{\{C,B\}}{Max} \quad U(C,B) \\ \text{Subject to} \quad I = p_1 C + p_2 B \end{cases}$$

The Lagrangian of this problem is

$$L = U(C,B) + \lambda(I - p_1 C - p_2 B)$$

The first order conditions give us

$$\begin{cases} U'_C = \lambda p_1 \\ U'_B = \lambda p_2 \\ U'_\lambda = I - p_1 C - p_2 B \end{cases}$$

From which we can deduce the Substitution Marginal Rate ($SMR_{B,C}$) between Biodiversity and Consumption

$$\frac{U'_C}{U'_B} = \frac{p_1}{p_2}$$

We consider now that the utility function is such that

$$U(C,B) = \ln C + \sigma_B \ln B$$

The relative preference for biodiversity σ_B is defined such that

$$\sigma_B = \frac{BU'_B}{CU'_C}$$

We have therefore

$$\text{SMR}_{B,C} = \frac{U'_C}{U'_B} = \frac{B}{\sigma_B C} = \frac{p_1}{p_2} \text{ and so } B = \frac{p_1}{p_2}\sigma_B C$$

We can deduce from this expression of B that U'_λ becomes

$$I = p_1 C + p_1 \sigma_B C = p_1 C(1+\sigma_B)$$

and finally that the optimal levels of Consumption and Biodiversity are

$$C^* = \frac{I}{p_1(1+\sigma_B)} \text{ and } B^* = \frac{\sigma_B I}{p_2(1+\sigma_B)}$$

Those two expressions allow us to analyze the evolution of consumption and biodiversity in two extreme cases, and to realize that those evolutions depend on individuals' relative preference for biodiversity. In the first case (1), individuals' relative preferences for

biodiversity (σ_B) tends to be zero, the enjoyment of B is non-existent and all the income is spent to consume private goods. In the second case (2), individuals' relative preference for biodiversity tends to be infinite and the consumption is therefore non-existent while all the income is spent to enjoy biodiversity.

$$(1)\begin{cases}\lim\limits_{\sigma_B\to 0} C = \dfrac{I}{p_1}\\ \lim\limits_{\sigma_B\to 0} B = 0\end{cases} \qquad (2)\begin{cases}\lim\limits_{\sigma_B\to +\infty} C = 0\\ \lim\limits_{\sigma_B\to +\infty} B = \dfrac{I}{p_2}\end{cases}$$

The more individuals prefer biodiversity relatively to consumption, the more income they will devote to enjoying biodiversity rather than consuming. The range of possible public policies that can be made to preserve biodiversity in such a context is limited. The central planer can influence the relative preference for biodiversity, $\sigma_B = \dfrac{BU'_B}{CU'_C}$ and so either influence the marginal utility individuals derive from consumption or the marginal utility they derive from biodiversity. It is possible for instance to organize public campaigns that lower U'_C by making consumers more environmentally responsible or even guilty of consuming, or that increase U'_B by revealing to the public the goods and services that they derive from biodiversity. However, a strong increase in this U'_B may result in the increase of recreational outdoors activities - all the income would be devoted to enjoying biodiversity- which may ultimately degrades nature. Therefore, rather than influencing the marginal utilities of individuals, the social planer can decide to tax biodiversity's use such that the income constraint writes

$$I = p_1 C + p_2(1+\tau)B.$$

The interpretation and the overall conception of biodiversity issues that can be done here is very limited. Biodiversity is seen as a good and dealt with as with a private consumption good. In addition, the hypothesis of endogeneity of the relative preference for biodiversity forces biodiversity to be compared to private goods and to be substitutable with them. This is a purely instrumental approach that neglects the actual essence of biodiversity by assimilating it to a good or a natural resource, and that neglects the contribution of biodiversity in the provision of private goods.

2.6.2. Dynamic optimization models

Sophistications can obviously be added to this simple model, among them considering the evolution of consumption and biodiversity with the time. We first consider a case (D1) in which utility is only derived from consumption C, which deteriorates biodiversity B. Biodiversity is therefore seen as a constraint, which has however a regeneration capacity of a rate r such that the evolution of the stock of biodiversity B is

$$\dot{B} = rB - C \,.$$

The program of maximization for the social planer is therefore

$$\text{(D1)} \begin{cases} \underset{\{C\}}{Max} \int_0^{\infty} U(C) e^{-\rho t} dt \\ \text{Subject to} \quad \dot{B} = rB - C \\ \qquad\qquad B_t \geq 0,\ B_0 \ given \\ \qquad\qquad C_t \geq 0 \\ \qquad\qquad 0 < \rho < 1 \ and \ 0 \leq r \leq 1 \end{cases}$$

U is a continuous function, twice derivable, concave and such as for any B, B > 0, $U_c > 0$, $U_b > 0$ and $U_{cc} > 0$. ρ is the discounting rate.

The Hamiltonian writes

$$H = U(C) + \lambda_1 [rB - C]$$

The first order constraints give us

$$\begin{cases} U'_C = \lambda_1 \\ \dot{\lambda}_1 = e\lambda_1 - \dfrac{\partial H}{\partial B} \\ \dot{B} = rB - C \end{cases} \Leftrightarrow \begin{cases} U'_C = \lambda_1 \\ \dot{\lambda}_1 = e\lambda_1 - r\lambda_1 \\ \dot{B} = rB - C \end{cases} \Leftrightarrow \begin{cases} U'_C = \lambda_1 \quad (1.1) \\ \dfrac{\dot{\lambda}_1}{\lambda_1} = -(r - e) \quad (1.2) \\ \dfrac{\dot{B}}{B} = r - \dfrac{C}{B} \quad (1.3) \end{cases}$$

We introduce a simple specification of the utility function which is

$$U(C) = \ln C$$

Therefore (1.1.) gives $\frac{1}{C} = \lambda_1$ that we can transform into $-\ln C = \ln \lambda_1$. We can deduce that

$-\frac{\dot{C}}{C} = \frac{\dot{\lambda}_1}{\lambda_1}$ and that $\frac{\dot{C}}{C} = r - e$ = g_1, the growth rate of consumption.

We are looking for a stationary solution. $x = \frac{C}{B}$ implies that

$$\frac{\dot{x}}{x} = \frac{\dot{C}}{C} - \frac{\dot{B}}{B}$$

And gives a balanced growth path such that for $\dot{x} = 0$ we have

$$\frac{\dot{C}}{C} = \frac{\dot{B}}{B} = g_1 \text{ (1.4) and } \frac{\dot{\lambda}_1}{\lambda_1} = -g_1 \text{ (1 .5)}$$

Supposing that B_0 is given, we deduce from (1.4) that $B_t = B_O e^{g_1 t}$, that $C_t = C_O e^{g_1 t}$. Also,

$x = \frac{C}{B}$, so $C_0 = x^* B_O$

However, for finding x*, $\dot{x} = 0$ so

$$\frac{\dot{x}}{x} = \frac{\dot{C}}{C} - \frac{\dot{B}}{B} = 0 \Leftrightarrow r - e - (r - x) = 0 \Leftrightarrow x^* = e$$

So $C_0 = eB_O$ and $C_t = eB_0 e^{g_1 t}$. From (1.5), we also deduce that $\lambda_t = \lambda_0 e^{-g_1 t}$. $\forall t, \lambda_t = U'_C(C_t)$, therefore

$$\lambda_0 = U'_C(C_0) = \frac{1}{C_0} = \frac{1}{eB_0}$$

$$\text{And so } \lambda_t = \frac{1}{eB_0} e^{-g_1 t}.$$

Before analyzing our results, we now consider a dynamic version of the static model, in which utility is derived from consumption and enjoyment of biodiversity, and we analyze the difference in result wit (D1). The utility function is now $U(C,B) = \ln C + \sigma_B \ln B$.

The first order constraints give us

$$(D2)\begin{cases} U'_C = \lambda_2 \quad (1.6) \\ \dfrac{\dot{\lambda}_2}{\lambda_2} = -(r-e) - \dfrac{U'_B}{U'_C} \quad (1.7) \\ \dfrac{\dot{B}}{B} = r - \dfrac{C}{B} \quad (1.8) \end{cases}$$

From (1.6), we deduce that $\frac{1}{C} = \lambda_2$ and like in the previous case, that $\frac{\dot{C}}{C} = -\frac{\dot{\lambda}_2}{\lambda_2}$. So $\frac{\dot{C}}{C} = (r-e) + \frac{U'_B}{U'_C}$ that we call g_2. Because $g_1 = r - e$, we can observe that $g_1 < g_2$. In addition, because $\sigma_B = \frac{BU'_B}{CU'_C}$ and $x = \frac{C}{B}$, we have $g_2 = r - e + \sigma_B \frac{C}{B} = r - e + \sigma_B x$.

On the BGP, $\frac{\dot{x}}{x} = 0$. Because $x = \frac{C}{B}, \frac{\dot{x}}{x} = \frac{\dot{C}}{C} - \frac{\dot{B}}{B}$ we have on the balanced growth path

$$\frac{\dot{x}}{x} = 0 \Leftrightarrow r - e + \sigma_B x - r + x = 0$$

Which gives $x^* = \frac{e}{1+\sigma_B}$ and $g_2 = (r-e) + \sigma_B \frac{e}{1+\sigma_B} = g_1 + \sigma_B \frac{e}{1+\sigma_B}$.

With B_0 given, we have $B_t = B_O e^{g_2 t}$, and $C_t = C_O e^{g_2 t} = x^* B_0 e^{g_2 t} = \frac{eB_0}{1+\sigma_B} e^{g_2 t}$. Finally, we have

$$\lambda_t = -g_2 = \lambda_0 e^{-g_2 t} = \frac{1}{C_0} e^{-g_2 t} = \left(\frac{1+\sigma_2}{eB_0} \right) e^{-g_2 t}.$$

By taking into account biodiversity as a source of utility rather than only a constraint in case D2, we observe again, like in the static case, that the relative preference for biodiversity influences the optimal paths of consumptions and biodiversity. However, biodiversity is still regarded as a good. The following graphs represent the two dynamic cases' results (for consumption, biodiversity and the social valuation of biodiversity λ). In the first case (D1), we have the expressions

$$C_t = eB_0 e^{g_1 t}$$

$$B_t = B_O e^{g_1 t}$$

$$\lambda_t = \frac{1}{eB_0} e^{-g_1 t}$$

And in the second case (D2) we have the expressions

$$C_t = \frac{eB_0}{1+\sigma_B} e^{g_2 t}$$

$$B_t = B_O e^{g_2 t}$$

$$\lambda_t = \left(\frac{1+\sigma_B}{eB_0} \right) e^{-g_2 t}$$

The strong hypothesis of this model leads biodiversity and consumption to grow at the same rate, whether individuals' valuation of biodiversity is taken into account or not in the utility function.

Figure 19: Evolution paths of Consumption and Biodiversity with the time in cases 1 and 2

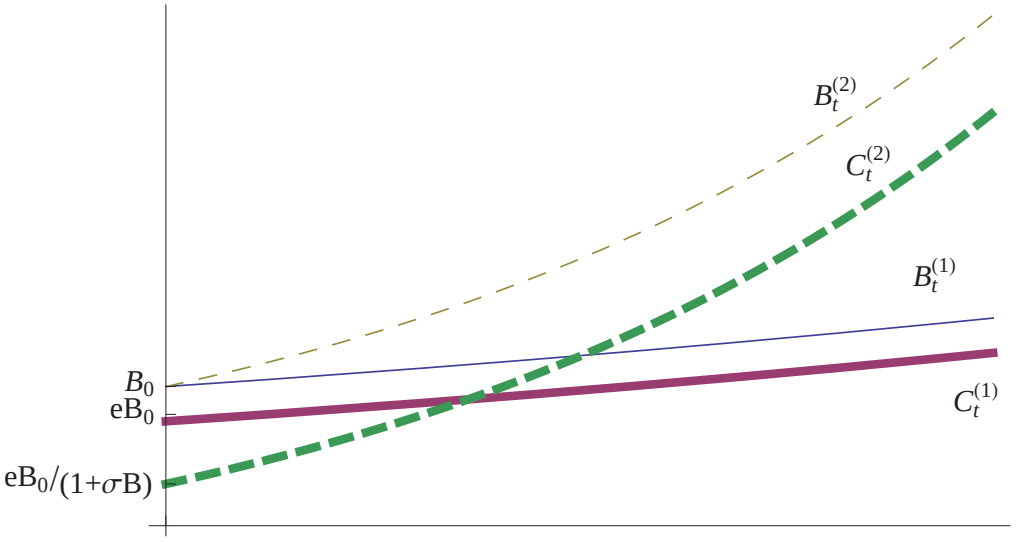
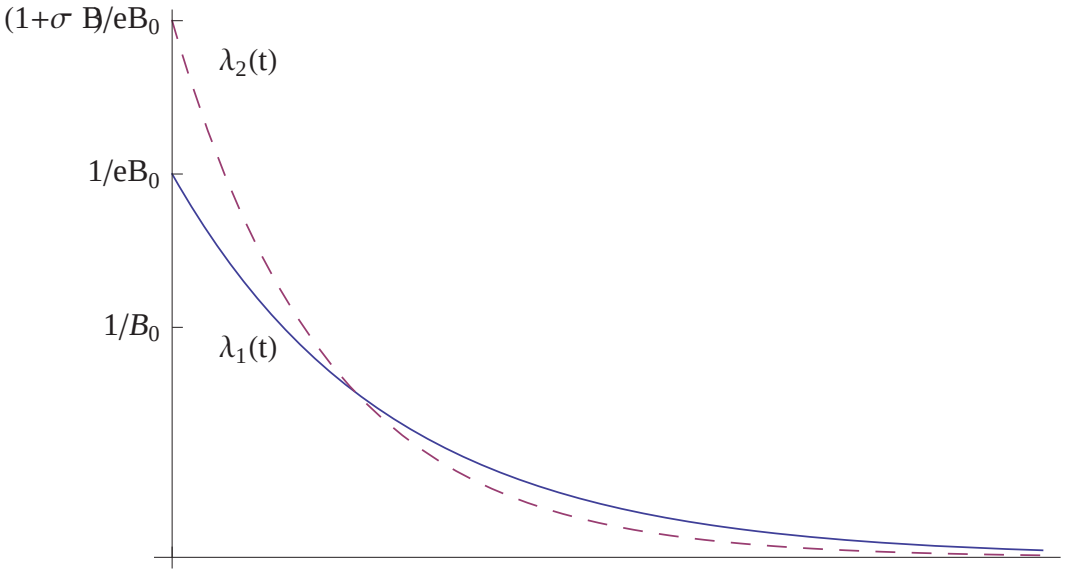


Figure 20: Evolution paths of the social valuation of biodiversity by individuals in cases 1 and 2



The complexity of the nature of biodiversity is not revealed here, and cannot be because the initial conception of what biodiversity is. Not technical sophistication can change this fundamental vision of biodiversity, a conceptual improvement is required.

2.7. Conclusion

Before playing a role in the decision making process, monetary valuations of biodiversity must be identified as tools that are not ethically neutral. While economics as a discipline already focus on human values/preferences and adopt an anthropocentric and instrumental approach to biodiversity, monetary valuations of biodiversity can bring a more restrictive approach to biodiversity and impose a strong anthropocentric and merely instrumental approach. While evidence exists to support this assertion, a review of all existing valuation methods and the dimensions of biodiversity they are applied to, would be necessarily to assess that monetary valuations of biodiversity always have this effect. In addition, it would be interesting to test empirically if valuations assumed to make the approach a SA and MI, actually help in practice to preserve biodiversity and ultimately help to preserve WA and I values. Lessons could be drawn from such research and be useful for interdisciplinary research.

ANNEXES

Annex 2.1: definitions of economics reviewed in Backhouse and Medema (2009)

(1) Krugman and Wells (2004), Microeconomics, New York: Worth.
Economics is the study of economies, at both the level of individuals and of society as a whole (p. 2).

(2) Colander (2006), Economics, 6th ed. Boston: McGraw-Hill Irwin.
Economics is the study of how human beings coordinate their wants and desires, given the decision-making mechanisms, social customs, and political realities of the society (p. 4).

(3) Mankiw (2001), Principles of Economics, 2nd Ed, Forth Worth: Harcourt Publishers.
Economics is the study of how society manages its scarce resources (p. 4).

(4) Bade and Parkin (2002), Foundations of Microeconomics. Boston: Addison Wesley.
[Economics is the] social science that studies the choices that individuals, businesses, governments, and entire societies make as they cope with scarcity (p. 5).

(5) Gwartney, Stroup, Sobel, and MacPherson (2006), Microeconomics: Private and Public Choice, 11th edition, Mason, OH: Thomson.
[E]conomics is the study of human behavior, with a particular focus on human decision making (p. 5).

(6) Smith (1776) [1976], An Inquiry into the Nature and Causes of the Wealth of Nations, Oxford: Oxford University Press.
"A branch of the science of a statesman or legislator". His *Inquiry into the Nature and Causes of the Wealth of Nations* (1776, p. 428) explained the relative fortunes of different countries, as well as the policies that might "enrich both the people and the sovereign."

(7) Say (1803) [1834], A Treatise on Political Economy; or the Production, Distribution, and Consumption of Wealth, Clement C. Biddle, Philadelphia, PA: Grigg and Elliot.
"Science" that treats "the production, distribution, and consumption of wealth."

(8) Mill (1844) [1967], On the Definition of Political Economy and on the Method of Investigation Proper to It, In Essays on Some Unsettled Questions of Political Economy, reprinted in Essays on Economics and Society, 1824–1845, The Collected Works of John Stuart Mill, Vol.4. Toronto:
University of Toronto Press.

"The science which traces the laws of such of the phenomena of society as arise from the combined operations of mankind for the production of wealth, in so far as those phenomena are not modified by the pursuit of any other object." (p. 323)

(9) Richard Whately (1832), Introductory Lectures on Political Economy, 2nd ed. London: B. Fellowes.
"Catallactics"—the science of exchanges

(10) Carl Menger (1871) [1976], Principles of Economics, New York: New York University Press.
Economics is "related to the practical activities of economizing men." (p. 48)

(11) Jevons (1871) [1965], The Theory of Political Economy. 5th ed. London: Macmillan.
Depiction of economics as "a calculus of pleasure and pain." (p. vi)

(12) Marshall (1890), [1920], Principles of Political Economy, 8th ed. London: Macmillan.
"Political Economy or Economics is a study of mankind in the ordinary business of life; it examines that part of individual and social action which is most closely connected with the attainment and with the use of the material requisites of wellbeing. . . . Thus it is on the one side a study of wealth; and on the other, and more important side, a part of the study of man." (1.1.1–2)

(13) Wicksell (1901) [1934], Lectures on Political Economy, Vol.1, London: Routledge and Wicksteed (1910), The Common Sense of Political Economy, London: Macmillan.
"Economics was about economizing—the elimination of waste in the administration of resources."

(14) Wicksteed (1910)
Economists are examining "the general principles of administration of resources, whether of an individual, a household, a business, or a State." (p. 17)

(15) Robbins (1932) [1935], An Essay on the Nature and Significance of Economic Science,
London: Macmillan.
"The science which studies human behavior as a relationship between ends and scarce means which have alternative uses." (p. 15)

(16) Ely, Adams, Lorenz, and Young (1926), Outlines of Economics, 4th ed. New York: Macmillan.
Economics was about "the wealth getting and wealth-using activities of Man"

(17) Slichter (1931), Modern Economic Society, New York: Holt.
"The subject matter of economics is industry, the process by which men get a living . . . economics studies industry, not as a technological process, but as a complex of human practices and relationships." (p. 11)

(18) Parsons (1937), The Structure of Social Action. New York: McGraw-Hill; and Spengler (1948), "The Problem of Order in Economic Affairs", *Southern Economic Journal*, 15, pp.1–29. Concerned with the subject of rationality

(19) Campbell McConnell's (1960), Elementary Economics: Principles, Problems and Policies, New York: McGraw-Hill.
"Recalling that wants are unlimited and resources are scarce, economics can be defined as *the social science concerned with the problem of using or administering scarce resources* (*the means of producing*) *so as to attain the greatest or maximum fulfilment of our unlimited wants (the goal of producing).*" (p. 23)

(20) Samuelson and Temin (1976), Economics, 10th Ed, New York: McGraw Hill.
"Economics is the study of how people and society end up choosing, with or without the use of money, to employ scarce productive resources that could have alternative uses, to produce various commodities and distribute them for consumption, now or in the future, among various persons and groups in society. It analyzes the costs and benefits of improving patterns of resource allocation." (p.3)

(21) Friedman (1962), Price Theory: A Provisional Text, Chicago: Aldine.
"The science of how a particular society solves its economic problems," where "An economic problem exists whenever *scarce* means are used to satisfy *alternative ends*" (p. 6).

(22) Stigler (1942), The Theory of Competitive Price, New York: Macmillan.
"The study of the principles governing the allocation of scarce resources among competing ends when the objective of the allocation is to *maximize* the attainment of the ends." (p. 12)

(23) Becker (1976), "The Economic Approach to Human Behavior", The Economic Approach to Human Behavior, 3–14, Chicago: University of Chicago Press,
"The combined assumptions of maximizing behavior, market equilibrium, and stable preferences, used relentlessly and unflinchingly, form the heart of the economic approach as I see it." (p. 5)

(24) Buchanan (1964), "What Should Economists Do?", *Southern Economic Journal*, 30(3): 213–22.
"The study of the whole system of exchange relationships" (p. 220)

Annex 2.2.: Calculations for the static model

$$L = \sigma_1 x_1 + \sigma_2 x_2 + \lambda(I - p_1 x_1 - p_2 x_2).$$

$$\begin{cases} L'_{x_1} = \sigma_1 - \lambda_1 p_1 = 0 \\ L'_{x_2} = \sigma_2 - \lambda_2 p_2 = 0 \\ L'_{\lambda} = I - p_1 x_1 - p_2 x_2 = 0 \end{cases} \Leftrightarrow \begin{cases} \lambda_1 = \sigma_1 / p_1 \quad (1) \\ \lambda_2 = \sigma_2 / p_2 \quad (2) \\ I = p_1 x_1 + p_2 x_2 \quad (3) \end{cases} \Leftrightarrow$$

$$\begin{cases} (1) = (2) : p_2 = (\sigma_2 \times p_1)/\sigma_1 \quad (4) \\ I = p_1 x_1 + p_2 x_2 \end{cases} \Leftrightarrow \text{(4) in (3)} \; I = p_1 x_1 + x_2(\sigma_2 \times p_1)/\sigma_1 \quad (5)$$

$$\Leftrightarrow x_1 = (I - x_2(\sigma_2 \times p_1)/\sigma_1)/p_1$$

$$\Leftrightarrow x_1 = I/p_1 - x_2\sigma_2/\sigma_1$$

and $x_2 = (I/p_1 - x_1)\sigma_1/\sigma_2$

REFERENCES

ALLEN Bryon and LOOMIS John B. (2006), “Deriving value for the ecological support function of wildlife: an indirect valuation approach”, *Ecological Economics*, N.56, pp.49-57.

ARROW Kenneth J. and FISHER Anthony C. (1974), “Environmental preservation, uncertainty and irreversibility”, *The Quarterly Journal of Economics*, pp.312-319.

ARROW Kenneth J., SOLOW Robert, PORTNEY Paul R., LEAMER Edward E., RADNER Roy and SCHUMAN Howard (1993), “Report of the NOAA Panel on Contingent Valuation”, 66p.

BACKHOUSE Roger E. and MEDEMA Steven G. (2009), “Retrospectives on the Definition of Economics”, *Journal of Economic Perspectives*, Vol.23, N.1, pp.221–233.

BAGGINI Julian and FOSL Peter S. (2007), The ethics toolkit: a compendium of ethical concepts of methods, Black well publishing.

BARRETT C. B. and GRIZZLE R. E. (1999), "A Holistic Approach to Sustainability Based on Pluralism Stewardship", *Environmental Ethics*, N.21, pp.23-42.

BEAUMONT N.J., M.C. AUSTEN, S.C. MANGI and M. TOWNSENDT (2008), "Economic valuation for the conservation of marine biodiversity", *Marine Pollution Bulletin*, N.56, pp.386-396.

BECKER Lawrence C. (Ed.) and BECKER Charlotte B. (1992), Encyclopedia of ethics, Garland Publishing Inc, New York and London.

BENSON John (2000), Environmental ethics: an introduction with readings, Routledge, New York.

BISHOP Richard C. et Thomas A. HEBERLEIN (1979), "Measuring values of extra-market goods: are indirect measures biased?", *American Journal of Agricultural Economics*, pp.926-930.

BLAUG Mark (1996), La pensée économique, Economica, 5th Ed .

BODDICE Rob (Ed.)(2011), Anthropocentrism : humans, animals, environments, Brill Editions.

BRAITHWAITE Victoria (2010), Do fish feel pain?, Oxford University Press.

BRENT J. Robert (2006), Applied Cost-Benefit Analysis, 2nd Edition, Edward Elgar, Cheltenham UK, Northampton, MA, USA.

BROOM D.M. and JOHNSON K.G. (1993), Stress and animal welfare, Ed. Chapman and Hall.

BROMLEY Daniel W. (2006), Sufficient reason: volitional pragmatism and the meaning of economic institutions, Princeton University Press.

BULLOCK Craig, Conor KRETSCH et Enda CANDON (2008), The Economic and Social Aspects of Biodiversity: Benefits and Costs of Biodiversity in Ireland, Government of Ireland, Dublin.

CANTO-SPERBER Dominique (1996), Dictionnaire d'éthique et de philosophie morale, Presses Universitaires de France.

CHADWICK Ruth and SCHROEDER Doris (2002), Applied Ethics: critical concepts in philosophy, Vol.IV: Environment, Routledge Edition, London and New York.

CLIFTON Don (2010), "Representing A Sustainable World: A Typology Approach", *Journal of Sustainable Development*, Vol.3, No.2, pp.40-57.

EHRLICH Paul R. et Anne H. EHRLICH (1992), "The value of biodiversity", *Ambio*, Vol.21, No.3, pp.219-226

FISKE Alan Page and TETLOCK Philip E. (1997), "Taboo trade-offs: reactions to transactions that transgress the spheres of justice", *Political psychology*, Vol.18, N.2., pp.255-297.

FRANKEL Herbert S. (1977), "Money: two philosophies. The conflict of trust and authority", Basil Blackwell.

GARROD Guy et Kenneth G. WILLIS (1999), Economic Valuation of the Environment: Methods and Case Studies, Edward Elgard.

HOF Patrick and VAN DER GUCHT Estel (2007), "Structure of the Cerebral Cortex of the Humpback Whale, Megaptera novaeangliae (Cetacea, Mysticeti, Balaenopteridae)", *The anatomical record*, N.290, pp.1–31.

KOSOY Nicolas and CORBERA Esteve (2010), "Payments for ecosystem services as commodity fetishism", *Ecological Economics*, Vol.69, Iss.6, pp.1228–1236.

LEBOUC Marie (2004), « La construction de l'altérité en contexte marchand : le cas de l'animal », Philosophiæ doctor (Ph.D.), Université Laval, Doctorat en sciences de l'administration, sous la direction de Michel AUDET.

LUDWIG Donald (2000), "Limitations of economic valuation of ecosystems", *Ecosystems*, N.3, pp.31-35.

MARKANDYA Anil, PERELET Renat, MASON Pamela et TAYLOR Tim (2001), Dictionary of environmental economics, Earthscan (Ed.).

MARIS Virginie (2010), Philosophie de la biodiversité : petite éthique pour une nature en péril, Ed. Buchet-Chastel.

MEDA Dominique (1999), Qu'est-ce que la richesse ?, Ed. Champs, Flammarion.

NORTON G. Bryan (2003), "Environmental ethics and weak anthropocentrism" in LIGHT Andrew and ROLSTON Holmes (Ed.) (2003), Environmental ethics: an anthology, Blackwell Publishing.

NUNES Paulo A.L.D. et Jeroen C.J.M. VAN DEN BERGH (2001), "Economic valuation of biodiversity: sense or nonsense?", *Ecological Economics*, N.39, pp.203–222.

OECD (Organisation for Economic Co-operation and Development) (2001), "Valuation of biodiversity benefits: selected studies".

O'NEILL John (2003), « The varieties of intrinsic value », in LIGHT Andrew and ROLSTON Holmes (Ed.) (2003), Environmental ethics: an anthology, Blackwell Publishing.

PEARCE David W. (2007), « Do we really care about biodiversity? », chapter 1, pp.22-54, in KONTOLEON Andreas, PASCUAL Unai and SWANSON Timothy (2007), Biodiversity Economics, University College London / or (2007), *Environmental and Resource Economics*, Vol.37, Issue 1, pp.313-333).

PICAVET Emmanuel (2011) « Réflexions sur le partage rationnel/ irrationnel », Printemps des Sciences Humaines et Sociales, « (Se) décider ? - Rationalité et irrationalité de la décision », http://www.meshs.fr/page.php?r=146&id=1274&lang=fr, consulté le 19 janvier 2012

PLATER et al. (2004), Environmental law and policy: Nature, law, and Society, Third Edition, Aspen publishers.

POJMAN Louis P. (2001), Environmental Ethics: readings in theory and application, 3rd Edition, Wadsworth.

REGAN Tom (2009), « How not to answer moral questions », in CAHN Steven M. (2009), Exploring ethics: an introductory anthology, Oxford University Press, New York.

REY Alain (2006), Dictionnaire historique de la langue française, Ed. Le Robert.

SAMUELSON Alain (1997), Les grands courants de la pensée économique : concepts de base et questions essentielles, 5ème Ed., Presses universitaires de Grenoble.

SAX Boria (2011), "What is this quintessence of dust? The concept of the human and its origins" in BODDICE Rob (Ed.)(2011), Anthropocentrism : humans, animals, environments, Brill Editions.

SCHERRER Sylvie (2004), Comment évaluer les biens et services environnementaux ? *La documentation française*, Réponses environnement.

SOBER Elliott (2002), "Philosophical problems for environmentalism", in CHADWICK Ruth and SCHROEDER Doris (2002), Applies Ethics: critical concepts in philosophy, Vol.IV: Environment, Routledge Edition, London and New York.

TEEB (2010), The Economics of Ecosystems and Biodiversity: Ecological and Economics Foundations, Ed. Pushpam KUMAR, Earthscan, London and Washington.

VATN Arild and BROMLEY Daniel W. (1994), "Choices without prices without apologies", *Journal of Environmental Economics and Management*, N.26, pp.129-148.

VIVERET Patrick (2010), Reconsidérer la richesse, Ed. l'aube poche

WILSON Edward O. (2012), The social conquest of earth, Ed. Liveright.

ZUINDEAU Bertrand (Ed.) (2000), Développement durable et territoires, Presses Universitaires du Septentrion.

ESSAY 3. The evolution of hyperbolic discounting: Implications for truly social valuation of the future[67]

Co-written with John Gowdy[68] and J. Barkley Rosser[69]

Abstract

We explore the standard expected utility model and alternatives to it. We then examine the behavioral and neurological evidence for hyperbolic discounting. We discuss evidence related to the neurological and behavioral evolution of discounting in non-human animals and in humans. We explore new findings about the importance of sociality in human behavior and the implications for truly social time preference. Finally, we discuss the implications of the neurological evidence on discounting for social environmental valuation, in particular the implications for very long-run decisions such as those involved in climate change mitigation and biodiversity preservation.

3.1. The basic economics of discounting

Evaluating the impacts of present activities on those living in the future is one of the most critical areas of uncertainty in environmental policy. The debate surrounding discounting is not only important to the numerical valuation of the costs and benefits of environmental policies (social benefits/costs and optimal path calculations), it is also central to designing policies that are incentive compatible with observed human behavior and evolved neurological structures and pathways. In the standard economic model—here referred to as the discounted utility (DU) model—the debate about responsibility to future generations is reduced to the choice of a social discount rate (Dasgupta and Heal, 1974; Hepburn et al., 2009; Pearce et al., 2003). Discounted utility refers to the discounted value of the flow of

[67] Article published in the Journal of Economic Behavior & Organization, June 2013, pp. 94–104.
[68] Departments of Economics and Science and Technology Studies, Rensselaer Polytechnic Institute, Troy, NY 12140, 3 USA.
[69] James Madison University, Harrisonburg, VA 4 22807, USA.

services from consumer goods over time (Ramsey, 1928; Samuelson, 1937)[70]. DU assumes a strict equivalence between benefits and the utility derived from those benefits. It is essentially a financial investment model showing how a perfectly rational individual should allocate investments so as to maximize expected present value of those investments. The standard DU model of environmental valuation assumes that social decision makers, like an individual making private investments, should seek to maximize the sum of present and discounted future economic welfare. In the DU framework, issues of intergenerational fairness are tied to the discount rate by both the pure rate time preference and the elasticity of marginal utility. The social discount rate is typically the private rate adjusted for external effects, and determining the scope of these effects is fraught with difficulties (Graaff, 1987). In the DU model, the value of future welfare is usually discounted at constant percent per year reflecting among other things society's impatience, or the preference for receiving benefits in the short run while deferring costs to the future.

In a continuous-time setting with constant population and a single consumption good, the DU approach employs the mathematics of constrained optimization to maximize the social welfare functional:

$$W(t) = \int U[C(t)]\left[\frac{1}{(1+r)^{\alpha(t)}}\right]dt \qquad (1)$$

In this form, U is instantaneous utility, C is the flow of consumption goods and $[1/(1+r)^{\alpha(t)}]$ is the discount weight. Using a constant discount rate reduces the weighting factor used in Eq. (1) to $[1/(1+r)^{t}]$, where α(t) = t (Albrecht and Weber, 1995; Caines and van der Pol, 2000). Eq. (1) is a general formula that can be converted into an exponential or hyperbolic function.

We must note that in the standard approach, this discount rate r is based on more fundamental elements, drawing on arguments of Ramsey (1928), Cass (1965), and Koopmans (1965). This formulation has the appropriate discount rate to be used to be the sum of a pure rate of time preference, ρ and the curvature of the utility of income, θ times the expected growth rate of output, g, that is,

[70] The DU model, referred to variously as "discounted utilitarianism", the "Ramsey model" or the "Ramsey–Cass–Koopmans" model is perhaps the most widely used deterministic model in general equilibrium economics. A variation is the dynamic stochastic general equilibrium model (DSGE) which is a specific application in macroeconomic models allowing for uncertainty.

$$r = \rho + \theta g\,, \quad (2)$$

Where

$$\theta = \frac{u''(c)c}{u'(c)}, \quad (3)$$

which is generally thought to lie between zero and one.

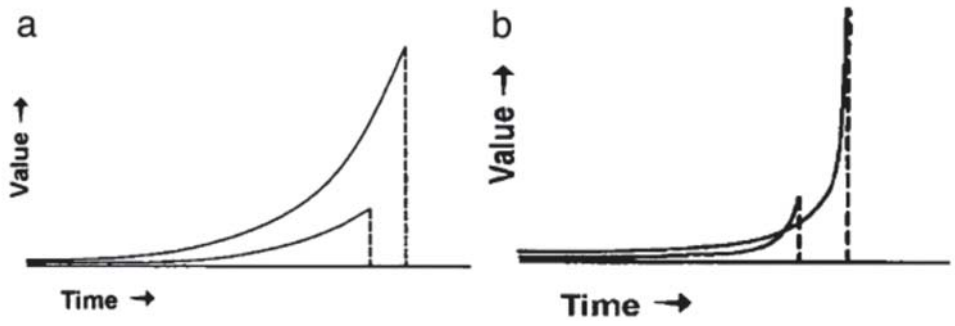
Even before getting into the issues of main interest for this paper, this formulation raises some issues. The first involves the fact that this formulation assumes that the economy is a single agent. That is problematic in itself. The next involves the determination of ρ, the social rate of time preference. Famously Ramsey himself declared that this should be zero on moral grounds, calling positive time preference rates to be "telescopic myopia." However, even if Ramsey's wish is followed through on, this formula will still deliver a positive discount rate to be used in (1) as long as future growth is expected to be continued and to be valued. Ironically, if there is a failure to adequately deal with global environmental problems, this expected g could possibly become negative, which could potentially lead to a negative r, although such a prospect is rarely taken seriously.

In spite of sustained criticism (Bromley, 1990; Frederick et al., 2002; Howarth, 2009; Ludwig et al., 2005) the DU model still dominates econometric work in environmental valuation including discussions of whether or not economies are sustainable (Arrow et al., 2004). Discussion of the proper discount rate was central to the controversies surrounding the Stern Review (Cole, 2008; Quiggin, 2008; Stern, 2007) on the economics of climate change and The Economics of Ecosystems and Biodiversity (TEEB) initiative on the economics of biodiversity loss (Gowdy et al., 2010). The upshot of these discussions is that there is no purely economic justification for choosing a particular discount rate. Econometric studies offer little guidance since even with fairly short-lived choices people employ a wide range of discount rates depending on framing, the nature of the product, income, and numerous other factors. For example, estimates of the discount rate for the adoption of energy saving appliances show inconsistent and widely varying time horizons. Hausman (1979) found that air conditioner purchases showed a discount rate of 25 percent and that the rate varied between 5 percent for high income households and 89 percent for low income households. Train (1985) found that discount rates varied considerably depending on the kind of appliance.

Hausman's results indicate that households discount the future benefits of energy appliances at rates far higher than the risk adjusted market rate of return. There are several ways to interpret this. One possibility is that people have different rates of return for different kinds of investments, a result widely at odds with the DU model (see Frederick et al., 2002). Another possibility is that people are not maximizing the present value of their investments which means that preferences cannot be described in terms of discount rates (Howarth and Sanstad, 2005). Hausman's (1979) and other similar studies calculate internal rates of return on particular investments assuming rational, maximizing behavior and their assumptions seem questionable given the findings. Howarth and Sanstad, 2005 argue that the extremely high discount rates for energy efficient appliances arise from asymmetric information, bounded rationality and transaction costs. It should also be mentioned that discounted utility models have played a key role in the analysis of investment behavior under uncertainty, particularly the debate over the equity premium puzzle (Ding et al., 2012).

Discounting is particularly problematic when dealing with extremely long-lived environmental problems like biodiversity loss, climate change and the risks associated with nuclear power (Carson and Roth Tran, 2009; Gowdy, 1997). Earlier it was sometimes argued that the discount rate should be based on the after-tax marginal rate of return on private investment as the best measure of the opportunity cost of capital, although that view has since been superseded by the view that a broader social consideration should dominate (Baumol, 1968; Marglin, 1963). The earlier view underlay the effort in 1970 by the Nixon Administration to impose a government-wide 10 percent discount rate for use in all cost–benefit analysis (based on estimates by Stockfish, 1969). In standard environmental valuation, the welfare effects of changes in an environmental attribute are evaluated based on the gain or loss of social welfare (the shadow price of the policy) with or without the environmental attribute (Barbier, 2007; Mäler, 1985).

Figure 21. Exponential and hyperbolic discounting



A number of theoretical and behavioral economists, following influential papers by Phelps and Pollak (1968) and Laibson (1997) have called for the use of a hyperbolic discount rate on positive and normative grounds. With hyperbolic discounting α(t) is concave because the discounting factor declines as a hyperbolic function of time. α(t) can take a number of hyperbolic forms. For example, Loewenstein and Prelec (1992) propose a general form of the discount weight as $1/(1+gt)^{h/g}$ so that:

$$\alpha(t) = \frac{h\ln(1+gt)}{g\ln(1+r)}, \quad (4)$$

The parameter h determines the length of each perceived time period. As h approaches zero time perceived passes faster and faster so that the individual is indifferent between time periods as in the standard exponential model. As h approaches infinity perceived time does not change and so there is no discounting of the future. We will provide in this paper some empirical support for those assumptions. The parameter g shows how much the function deviates from the standard exponential model. The fundamental difference between exponential and hyperbolic discounting is that the discount rate varies over time with the hyperbolic and not with the exponential. More normative recent research on discounting long-term environmental benefits and costs (Philibert, 1999) has also called for discount rates decreasing over time. Caines and van der Pol (2000) show how various hyperbolic models such as those of Harvey (1986) and Mazur (1987) are variations of Eq. (2).

In the context of the DU model, an argument for constant discounting is that it is time consistent, that is, the passage of time does not affect the investment decision (Winkler, 2006). Koopmans (1960) refers to this as the stationarity postulate. The preference between two outcomes depends only on the absolute time separating them, not the distance into the future. Hyperbolic discounting is time inconsistent because an optimal decision made at time t may no longer be optimal when re-evaluated at time t + 1 (Strotz, 1956). Fig. 1a shows exponential discount curves from a Smaller-Sooner (SS) reward and a Large-Latter (LL) reward. Fig. 1b shows hyperbolic discount curves from an SS reward and a LL reward. In the hyperbolic case the smaller reward is temporally preferred for a period just before it is available, as shown by the portion of its curve that projects above that from the LL reward (Ainslie, 2005).

This brings up the more general problem with the DU model. It is a normative model describing how a person at a point in time should (not actually does) make an investment decision, neglecting thereby empirical evidence about discounting behavior that could help make policies more incentive compatible. The DU model assumes strict rationality on the part of agents, in the form of rational expectations and time consistency, so that hyperbolic discounting is time inconsistent. Evaluations of the worth of something at a future date will vary significantly depending on the starting point (see Ackerman and Heinzerling, 2004).

In the next section we first examine the behavioral and neurological evidence for hyperbolic discounting. We then discuss alternative (non-expected utility) approaches to discounting including those allowing for time inconsistency, matching laws and similarity-based decision making. We then turn to the neurological and behavioral evidence for the evolution of discounting in non-human animals and in humans. Finally, we discuss the implications of the neurological evidence on discounting for environmental valuation, in particular the implications for very long-run decisions such as those involved in climate change mitigation and biodiversity preservation policies. The discounting discussion takes us beyond DU approaches underlying most of contemporary environmental theory and policy and opens the door to a broader discussion of human well-being, the social context of decision-making, and aligning environmental policies with incentives compatible with observed human behavior.

3.2. Hyperbolic discounting

One form of a hyperbolically discounted utility function is given by Rubinstein (2003, p. 1207):

$$u(x_0, x_1, ..., x_t, ...) = v(x_0) + \beta \sum_{t=1,2,...} \delta^t v(x_t) \qquad (5)$$

Utility received in periods 0, 1, 2, 3,… is discounted by $1, \beta\delta, \beta\delta^2, \beta\delta^3, \ldots$, respectively. This function implies that the value of the ratio of rewards received in successive time periods becomes smaller and smaller the further in the future they occur.

Generally speaking, considerable evidence exists for some form of hyperbolic discounting in that people discount the value of delayed consumption more in the immediate future as opposed to the distant future (Cropper and Laibson, 1999; Kim and Zauberman, 2009; Newell and Pizer, 2003; Settle and Shogren, 2004; Weitzman, 2001). Ainslie (2005) shows that hyperbolic discounting can explain observed irregularities in human behavior such

as preference reversal and impulsive choices made when a reward is immediately available. But does this imply that individuals employ a continuous discounted utility function as implied by Eq. (2)? Rubinstein (2003) argues that the same evidence from behavioral experiments used to reject exponential discounting can also be used to reject hyperbolic discounting. He argues for "opening up the black box" of human decision making rather than simply modifying functional forms that can be easily accommodated in the standard welfare model. Hyperbolic discounting is "safe" because it can be incorporated into the standard economic optimization model as in the Nordhaus and Boyer (2000) climate change model. Hyperbolic discounting is frequently favored by environmental economists on ethical grounds because it gives more weight to losses suffered by future generations. But as Rubinstein (2003, p. 1215) observes:

[Hyperbolic discounting] goes much further than simply assigning a special role for the present. It assumes the maximization of a utility function with a specific structure and misses the core of the psychological decision-making process. Thus, I find it to be no more than a minor modification of the standard discounting approach.

Nevertheless, we note an important difference between the sort of hyperbolic discounting observed in individuals, such as the Hausman (1979) study of people buying appliances, and the sort advocated for social decision making by some environmental economists. The discount rates observed for individuals tends to take the form of very high short-term rates, with rates declining to something more like observed market rates for longer time horizons. The rates advocated by environmental economists tend to be much lower across the board, with the shorter horizon ones being nearer market rates, whereas the longer term ones decline toward zero. This reflects the "green golden rule" perspective of Chichilnisky et al. (1995) which argues that higher short term rates avoid having the future exploit the present (and also help efficiently allocate investment), while lower longer term rates guarantee that the present does not exploit the future. At the same time, none of these reflect what one observes in a normal market term structure of interest rates, wherein rates for longer term assets are usually higher than for shorter term ones, although this is conventionally explained by a rising inflation risk premium as one holds longer term assets. All this supports Frederick et al. (2002) argument that there is no convincing economic case for picking a particular discount rate. An examination of the behavioral arguments for hyperbolic discounting reinforces this view.

The existence of hyperbolic discounting—broadly defined as the tendency of people to discount the immediate future more heavily than the more distant future—is well documented (Frederick et al., 2002; Kirby, 1997; Kim and Zauberman, 2009; Loewenstein and Prelec, 1992; Thaler, 1981). This phenomenon has also been found in non-human animals (Ainslie, 1974; Green and Myerson, 1996) suggesting that discounting the immediate future more heavily has an evolutionary basis. Numerous behavioral experiments show various forms of hyperbolic discounting. But there is substantial variation in the way the discount rate changes through time and in the discount rates for various rewards. Estle et al. (2007) compared discounting of monetary rewards and discounting directly consumable goods (candy, soda and beer) and found that monetary rewards were discounted less steeply. Findings like this are only suggestive but the authors speculate that delayed monetary rewards are different than consumable goods because they are fungible and generalized as a representation of all consumer goods. If people discount money (or anything else) differently than directly consumable food items (or anything else) this implies that the search for an empirically revealed universal discount rate, hyperbolic or otherwise, is misplaced. However, even if there are no universal patterns, hyperbolic discounting may provide some insights for some specific aspects of decision-making and some specific types of rewards (Frederick et al., 2002).

Another variation is the perceived time model (Kim and Zauberman, 2009). In this model hyperbolic discounting occurs because people show diminishing sensitivity to longer time horizons and because of time contraction (one year is perceived to be less than four times three months). Related to this is Hernstein's matching law. In binary choice experiments people match their responses proportionately to reinforcement proportions rather than choosing the outcomes with the highest expected probable payoff (Ainslie, 2005; Fantino, 1998; Herrnstein, 1961). Ainslie (2005) points out that the hyperbolic discounting curve is a variant of Herrnstein's matching law described by the formula:

$$\text{value} = \frac{\text{value at no delay}}{\text{constant} + (\text{impatience factor } X \text{ delay})}$$

The constant is a small number describing the "failure of values to approach infinity as delays approach zero" (Ainslie, 2005, p. 636). By varying only the impatience factor, this simple formula can describe intertemporal choice in a wide variety of circumstances for a variety of rewards for both human and animal subjects.

Ainslie (2005) argues that hyperbolically based uncertainty about the future leads people to see current choices as “test cases” that establish a mental “model of willpower”. According to him (Ainslie, 2005, p. 636) his model explains “... how intertemporal bargaining leads to compulsive side effects and how a hyperbolically based impulse toward premature satiation of appetite gives emotions their quasi-voluntary quality and motivates the social construction of facts, the quest for vicarious experience, and indirect approaches to goals.” He puts an interesting twist on hyperbolic discounting with his idea of “the self as a population”. People have a variety of sometimes complementary and sometimes contradictory preferences that become dominant or submissive depending on social context, timing, and reward structures.

An agent who discounts a reward hyperbolically is not the straightforward value estimator that an exponential discounter is supposed to be. Rather, she will be a succession of estimators whose conclusions differ; as time elapses these estimators shift their relationship with one another from cooperation on a common goal to competition for mutually exclusive goals. Ulysses planning for the Sirens must treat Ulysses hearing them as a separate person, whom he must influence if possible and forestall if not. If what you do in a situation regularly gets undone later, you’ll learn to stop doing it in the first place—but not out of agreement with the later self that undoes it, only out of realism. Meanwhile you’ll look for steps toward getting what you want from the earlier vantage point, steps that won’t be undone, because they forestall a future self who will try to undo them. You’ll be like a group of people rather than a single individual; subjectively, however, the results of learning to do this may feel like no more than having to plan for self-control (Ainslie, 2005, p. 637).

Ainslie calls his approach picoeconomics, because individual choice is a kind of intertemporal bargaining involving “the strategic interaction of successive motivational states within the person.” Even single individuals are collections of biologically mediated and socially constructed “selves”. Multiple self theories are supported by neurological studies showing that different parts of the brain are involved, for example, in valuing immediate returns and delayed returns (McClure et al., 2004). It is also supported by behavioral studies showing that consumers’ preferences do not necessarily match citizens’ preferences (Sagoff, 1994).

The question of discounting not only moves quickly from economics to ethics, it also leads to the search for the “deep structures” of human society and human reasoning. An evolutionary perspective requires going beyond proximate causes of economic outcomes

(discount rates, prices and markets) to examine ultimate causes (institutional responses to resource availability and biophysical constraints and opportunities). The critical environmental choices we make today will affect humans living hundreds of generations in the future. Can we make decisions on behalf of future generations without knowing what sorts of economic and social value systems they will have? Will they think about numbers and discounting in the same ways we do? Numbers—meaning a working language system of words and symbols for exact quantities—probably emerged with agriculture and trade and are therefore no more than a few thousand years old. Theories of time and number perception have gotten a boost in recent years from cross-cultural studies of hunter-gatherer groups isolated from predominantly agricultural and industrial societies.

3.3. The evolutionary origins of discounting

The discounted utility approach assumes that people are rational and consistent in choosing a single discount rate that will maximize the present discounted value of a stream of future returns to investments. The lack of consistency in observed discount rates, the fact that individuals use different discount rates for different categories of things to be discounted, and the evidence for hyperbolic discounting, suggests that the standard approach is missing some deeper level of causality in explaining how people value the future. As mentioned above, a useful tool of evolutionary biology is the distinction between ultimate and proximate causation (Tinbergen, 1963). This concept asserts the need for two separate and complementary explanations for all products of genetic and cultural evolution. Ultimate causation explains why a given trait exists, compared to many other traits that could exist, based largely on the winnowing action of selection. Proximate causation explains how the trait exists in a mechanistic sense. It is especially important to recognize the many-to-one relationship between proximate and ultimate causation, whereby many functionally equivalent solutions can evolve in response to a given environmental challenge (Wilson and Gowdy, 2010). There are certainly economic reasons for why people discount the future—for example, the existence of investment opportunities for money received today. But an examination of the anthropological and neurological literature reveals another, deeper and more universal, explanation of discounting.

The ability to express numbers exactly (cardinally) seems to be a cultural artifact, not something we naturally acquire. A hunter-gatherer tribe deep in the Brazilian Amazon, the Mundurukú, has received considerable attention in recent years because they do not have an

exact number system. In fact they lack words for numbers above 5. The Mundurukú do not use numbers to refer to precise quantities. The word “five”, for example, can mean 5, but also 6, 7, 8 or 9 (Pica et al., 2004). Like people in literate cultures, the Mundurukú have a nonverbal number sense. They can distinguish between groups of different sizes: “They can mentally represent very large numbers of up to 80 dots, far beyond their naming range, and so not confuse number with other variables such as size and density. They also spontaneously apply concepts of addition, subtraction, and comparison to these approximate representations” (Pica et al., 2004, p. 503). Also like people in literate cultures, they exhibit a distance effect in comparing quantities; accuracy in comparing quantities improves as the ratio between the numbers to be compared increases. Pierre Pica tested the Mundurukú’s spatial understanding of numbers by testing how they visualized numbers on a computer screen:

Each volunteer was shown an unmarked line on a screen. To the left side of the line was one dot, to the right ten dots. Each volunteer was then shown random sets of between one and ten dots. For each set the subject had to point at where on the line he or she thought the number of dots should be located. Pica moved the cursor to this point and clicked. Through repeated clicks, he could see exactly how the Mundurukú spaced numbers between one and ten. (Bellos, 2010, p. 5).

The Mundurukú spaced the numbers so that the interval between numbers became smaller and smaller as the numbers increased. When the test is given to American adults they space the numbers at equal intervals. Stiegler and Booth (2004) found that kindergarten pupils, Like the Mundurukú, spaced numbers logarithmically. First grade students begin to space the numbers more equally, and by the second year of school student space the numbers equally along a line. These results are, of course, very tentative but suggest that some variation of hyperbolic valuation may represent some “deep structure” of human reasoning.

The behavior of non-human animals has also proved to be fertile ground for insights into how people value future rewards. In general, researchers have found that animals discount rewards hyperbolically (Green et al., 2010), that humans discount delayed rewards significantly less steeply than do other animals (Jimura et al., 2009), and that humans discriminate between reward amounts more than other animals do (Green and Myerson, 1996). The view is widespread that animal behavior justifies the economic rational actor model. Gintis (2006, p. 7) argues that the assumption of choice consistency among humans is justified by animal behavior. “Economic and biological theory thus have a natural affinity; the

choice consistency on which the rational actor model of economic theory depends is rendered plausible by biological evolutionary theory, and the optimization techniques pioneered by economic theorists are routinely applied and extended by biologists in modeling the behavior of a vast array of organisms." It is true that the standard rational optimization model has been applied successfully by biologists, for example, to examine optimal foraging strategies. In a classic optimal foraging study, Harper (1982) tested the ability of a flock of ducks to achieve a stable Nash equilibrium when fed balls of bread. Two researchers stood on the bank of a duck pond threw out 5 balls of dough at different intervals. The ducks acted according to expected utility theory and re-arranged their numbers efficiently as the payoffs were changed. In another animal experiment chimpanzees, unlike humans, appear to be rational maximizers in the ultimatum game (Jensen et al., 2007). But contrary to Gintis' assertion, humans do not exhibit the regularities in choice that other animals do. Regarding economists' claims for human "rationality", it is ironic that a large body of evidence suggests that "lower" animals seem to act more in accordance with the economic model of rational choice than do humans.

Both the duck pond experiment and the Mundurukú may be examples of the evolutionary advantage of recognizing ratios. McComb et al. (1994) performed an experiment with a pride of lions in the Serengeti. The researchers played a loudspeaker of the sound of one lion roaring as a single lion walked by on a path. In this case the lioness kept walking. When five lions were walking by, McComb et al. played the sound of three lions roaring and the five lions charged into the bushes to attack. The researchers postulated that lionesses were comparing relative quantities in their heads. One lion versus one other lion meant it was too risky to attack, but with a five to three advantage, the lions realized that an attack could be successful in driving the other animals away. Bellos (2010, p. 7) writes:

The precedence of approximations and ratios over exact numbers, Pica suggests, is due to the fact that ratios are much more important for survival in the wild than the ability to count. Faced with a group of spear-wielding adversaries, we needed to know instantly whether there were more of them than us. When we saw two trees we needed to know instantly which had more fruit handing from it. In neither case was it necessary to enumerate every enemy or every fruit individually. The crucial thing was to be able to make quick estimates of the relative amounts.

As mentioned above, Herrnstein's matching law has been found to hold in animal behavior. In his experiment (Herrnstein, 1961) pigeons were given the choice of two buttons

to peck with different rates of food reward for each choice. The pigeons tended to pick the button that gave the greatest reward but they were also influenced by the rate at which the reward was given—that is, they did not make decisions according to the expected payoff. But humans do not consistently behave according to the matching law (Bradshaw et al., 1976). Compared to other animals, humans generally take more account of the future consequences of their actions when making temporal decisions (Frederick et al., 2002). It has been argued that animals are "stuck in time" without the ability to anticipate long-term future events (Roberts, 2002). But this observation is not without caveats. Bonobos and chimpanzees show a degree of patience not present in other animals, humans are less willing to wait for food than are chimpanzees, and humans are more willing to wait for money than for food (Rosati et al., 2007).

Comparing discount rates between humans and other animals is complicated by the fact that animal studies rely solely on food rewards. A study comparing humans and other animals receiving delayed real liquid rewards showed a marked decrease in the delay humans were willing to accept compared to other animals (Jimura et al., 2009). McClure et al. (2004) used fMRI imaging to show that separate neural systems in the brain value immediate monetary rewards and delayed monetary rewards. That is, two separate neurological systems are involved in discounting money depending on the time length of the delay of the reward. An on-going debate is whether two distinct and competing brain systems are responsible for self-controlled or impulsive behavior or whether a single integrated system mediates subjective delay and the perceived value of outcomes (Wittmann and Paulus, 2009).

In summary, evidence suggests that hyperbolic discounting has an evolutionary basis. It may be speculated that an ultimate cause is the survival advantage of being able to quickly access ratios—the probably of relative amounts of food in foraging patches or the relative size of rival groups. A limitation of discounting studies is that they focus exclusively on individual discount rates. Even so-called social discount rates are simply individual rates adjusted for spillover effects. We conceive of social discounting as a process influenced by human sociality, in the case of individual discounting because individuals are members of particular social group and develop in their individual behavior a social dimension, or in the case of collective discounting because it emerges from a collective deliberation of a group. Current evidence from various fields points to the uniqueness of humans among mammals as social animals. Our success as a species is apparently due to our ability to cooperate and to make collective decisions for the good of the group (Nowak and Highfield, 2011; Sober and

Wilson, 1998; Henrich and Henrich, 2007). This is especially relevant to the valuation of likely future environmental outcomes because our viability as a species may depend on our ability to forge collective solutions to global problems like climate change and biodiversity loss.

3.4. Social discounting

What economists usually refer to as "social discounting" is really not social in the sense discussed above, except in the framework of the DU model where decisions are confined to the world of perfectly rational self-regarding agents operating under conditions of competitive equilibrium. In this world, the social discount rate (usually denoted by r) is "the appropriate value of r to use in computing present discount value for social investments" (Gruber, 2007). Justifications for discounting in public decisions mainly rely on the opportunity cost of the capital that will be spent for social investments. Indeed, especially for long-term environmental issues, public decisions deal with intergenerational equity and a positive pure time preference is rejected by some on the basis that "people's welfare should not be valued less simply because they live at a different time" (Philibert, 2006; Ramsey, 1928). Also, the assumption that the wealth effect will make future generations better off than the current generation as result of the economic growth might be incorrect, for example, if the environmental costs to be borne by future generations are extremely high, or when the beneficiaries in the future of current investments are from developing countries while the "investors" are from developed countries (Philibert, 2006). So in the standard economic model, the rate of return on the private financial benchmark investment is often reinterpreted as the social discount rate, which corresponds to a financial accounting approach (Pannell and Schilizzi, 2006). Thus, the social rate of discount is far from reflecting how individuals value the future as members of a particular social group. Rather, it normatively imposes the self-regarding rational representative agent standard which cannot alone represent the whole set of human individual and social behaviors.

Fiske and Tetlock (1997) provide empirical support of the impossibly of characterizing human behavior by a single rational calculative process. They highlight four different spheres of social relationships among which we find communal sharing (CS) and market pricing (MP) relationships. They underline how those four spheres are based on drastically different inherent logic, motives, normative forces, affective tones, moral foundations, metric and language and how trade-offs requiring using the language of one

sphere for dealing with another sphere appear unintelligible or even degrading for people. They conclude by arguing that empirical evidence exists that individuals establish an ordinal ranking of those spheres as following: Communal Sharing > Authority Ranking > Equality Matching > Market Pricing, underlying the non-substitutability of market and other relational approaches and especially the strong inadequacy of applying market logic to communal/social sharing affairs.

Whether the social discount rate is defined by a normative approach relying on benchmarking with the market interest rates, or by a more positive approach like hyperbolic discounting, the extent to which public decisions ought to be based on individuals' discounting behaviors remains unsolved. The major assumption of the standard economic approach – that social welfare measurements are based on summing individual preferences – legitimates the recourse to individuals' discounting behaviors as basis for social discounting. However, many problems have emerged from this approach. First, what is (positive) should not necessarily be the standard for what ought to be (normative), while it can help policies to be incentive compatible. Reasons for public investment decisions "run from the future back to the present, and not the other way around" (Bromley, 2006). Second, the issue of intergenerational distribution (and the willingness of members of the current generation to pay for actions that reduce risks faced by future generations) is different from the issue of present value maximization within one generation (and the impatience of members of the current generation) (Howarth, 2009; Schelling, 1995). Using the latter context for the former situation is problematic. Finally, as empirical results supporting hyperbolic discounting show, individuals fail to apprehend very-long term horizons and can be subject to preference reversals and time inconsistencies; characteristics that may be undesirable for public policies, already subjected to time inconsistencies resulting from political turnover. Another technical consideration for the proper role and use of social discount rates is that considerable ambiguities can arise with discount rates that can go against our usual expectations. For example, it is generally argued that since lower discount rates, hyperbolic or otherwise, give more value today for things happening far in the future than higher discount rates, using lower discount rates in intertemporal environmental decision making will lead to more environmentally friendly or ecologically sustainable outcomes. However, this may not always be the case, or at least not so unambiguously, particularly when there may be important opportunity costs of capital involved or complicated streams of net benefits over time (Tisdell, 2005). Ambiguity of the first sort was identified by Farzin (1984) for the case of

nonrenewable resources in the context of the Hotelling Theorem for their efficient intertemporal extraction. This involves considering capital-intensive extraction processes compared to some backstop substitute resource. A rise in the discount rate could increase the cost of extraction sufficiently to offset the time preference effect so that less might be extracted. Such offsets are more likely to occur when the resource is either very abundant or very scarce, which in the latter case could lead to the outcome that a lower discount rate could lead to the accelerated extraction of the scarce resource. But Hannesson (1987) showed that the above perverse effect could work in the case of renewable resources as well, particularly fisheries, so that if fishing is capital-intensive, a lowering of the discount rate could increase the threat of species extinction of a fish of low population size. In the renewable resource case Colin Clark (1990) showed that a sufficiently high discount rate might make it economically rational to harvest a species to extinction.

These cases share similarities with the problems that arise when net benefit streams over time can move from negative to positive to negative again, or exhibit even more complicated patterns. That this can lead to ambiguities was understood as far back as by Irving Fisher (1930) who identified such phenomena as leading to "multiple roots." The general issue was recognized among environmental and resource economists by Herfindahl and Kneese (1974), Fisher (1981), and Porter (1982), the latter noting the ambiguity such problems could imply for "preservation." While wilderness and endangered species might be valued more at lower discount rates, they might also benefit from the use of very high discount rates, such as the 10 percent rate imposed early in the Nixon Administration, which caused many environmentally damaging dam-building projects to fail cost-benefit tests due to their high upfront capital costs.

As this involves situations where one alternative is preferred at both low and high discount rates compared with another that is preferred at intermediate ones. This has led some observers to identify this issue with that of reswitching in the Cambridge controversies in the theory of capital (Harcourt, 1972; Sraffa, 1960), which involves precisely such paradoxes. The first to make this connection using an example of using machinery versus animals in certain agricultural practices was Peter Albin (1975). Prince and Rosser (1985) make a similar argument in comparing strip mining of coal with cattle grazing in the U.S. Southwest using realistic numbers and finding such reswitching within ranges of discount rates used in public policymaking, with the upfront and delayed costs of coal strip mining making it the activity preferred at intermediate discount rates. Finally, Asheim (2008) also made such an analysis

using the example of high upfront and distant costs of nuclear power. This suggests that considerable caution is due in making simple generalizations about the effect of different discount rates on environmental outcomes.

3.5. The social brain and social valuation of the future

Many animals are exceptional in their degree of sociality but scientists are just beginning to discover the uniqueness of humans in this regard. Unlike other primates, humans are able to form long-term cooperative bonds with non-kin. Hill et al. (2011) looked at co-residence patterns in foraging societies and found that humans, compared to other primates, are unique in that (1) either sex may remain with their parental group, (2) adult brothers and sisters may co-reside, (3) most members of a residential group are unrelated, and (4) preferential bonds are maintained with spouses' relatives and relatives' spouses. Generally, primary kin make up only 10 percent of a residential human band while in other primate groups most members are closely related. Human cooperative groups apparently have characteristics that enhance individual judgments. Woolley et al. (2010) found evidence for a "collective intelligence factor." In their study, groups of two to five people were assigned a variety of tasks then the groups were ranked according to their performance of these tasks. The researchers found that a collective intelligence factor explained differences in the groups' performance. Most importantly, this factor was not strongly correlated with individual characteristics such as IQ but rather the composition of the group (for example, the percentage of females) and the social sensitivity of group members.

The uniqueness and importance of human sociality has also been confirmed and enriched by neuroscience. The way the brain is organized and develops provides evidence of human sociality (Wexler, 2006). Most of the neurons in the human brain develop after birth and the way they are configured depends critically on how a child is socialized. It is another way that variability can be introduced into evolutionary mix. A finding from neuroscience is the presence in the human brain of Von Economo neurons (VENs) that may have evolved to enable people to make rapid decisions in ambiguous social contexts (Sherwood et al., 2008). VENs are located in cortical areas that are positioned at the interface between emotional and cognitive processing. Allman et al. (2005) speculate VENs are designed for quick signaling of an appropriate response in the context of social ambiguity, an ability that would be particularly important in the context of communities whose composition and hierarchical social arrangement is continually changing. The existence of VENs is important not only

because it provides physical evidence that preferences are genuinely other-regarding, but also because their existence implies that being strictly self-regarding is not the best way to make decisions. Indeed, if human evolution has led to the positive selection of VENs, which allow us to make fast intuitive assessments of complex social situations (Sherwood et al., 2008) then automatic responses, quick intuition and emotions must be critical to the human decision-making process. VENS might be related to the way humans view the distant future as in the intuitive logarithmic numerical scale identified by Pica and his colleagues (Pica et al., 2004). The distance effect and the reduced emotional involvement of individuals with far distant futures (cognitive capacities being more involved than impulsive capacities for long-term horizons) (Schmidt, 2010) might explain why individuals barely distinguish time intervals in the far distant future. This supports hyperbolic discounting for mid- and long-term futures.

Numerous authors argue that cooperation and compassion for others, not competition, explains the success of our species (Henrich and Henrich, 2007; Nowak and Highfield, 2011; Sober and Wilson, 1998). Foraging in human societies is an evolved social process and how we value resources cannot be fully understood without recognizing the importance of cooperation and rules for group survival in resource management. In our 200,000-year history humans have thrived in a variety of environments using a dazzling array of cooperative institutions to sustainably manage local resources. This research suggests that a strong case can be made for valuation processes allowing for interaction and deliberation among individuals (Gowdy and Parks, 2013; Howarth and Wilson, 2006). Such deliberation can capture information and deal with uncertainty in ways that isolated individuals cannot. There may also be an "ideal" composition of groups for making critical decisions. This raises many intriguing questions. For example, is there an ideal mix of selfish individuals and altruists in collective decision making? What role does gender play in successful group composition? Does voting based on isolated individual decisions preclude solutions based on group deliberative valuation that might result in better outcomes?

3.6. Conclusion – from hyperbolic discounting to truly social valuation of the future

Neuroscience, behavioral, and evolutionary studies provide support for the introduction of hyperbolic discounting as appropriate for some valuation and discounting situations. In addition, it seems to be able to grasp some social dimensions of human decision

making. However, many hypothesis and restrictions are necessary to apply hyperbolic discounting which reduces complex valuation decisions and human behavior to a functional form that can be easily accommodated in the standard welfare model (Rubinstein, 2003). We have exposed reasons for social discounting, or more broadly social valuation of the future, to be more than an aggregate of individual choices, and reasons for defending that what is (positive) should not necessarily be the standard for what ought to be (normative). Social discounting is a socially mediated construct based on cultural traditions that evolved under a variety of environmental conditions, perhaps most notably the climatic uncertainty of the succession of ice ages in human prehistory (Richerson and Boyd, 2005). Discounting finds its financial justification in the social opportunity cost of capital but once it is used for social investments, this justification hardly manages to offset the ethical implications of discounting regarding intergenerational equity and its required synthetic representation of major environmental issues. Especially for long-term threats like climate change and biodiversity losses, environmental valuations to be discounted suffer from our current lack of knowledge, high uncertainty and our weaknesses to act as regent of future generations' needs (Bromley, 2007; Gowdy, 2000; Gowdy and Parks, 2013). As a result, current economic approaches providing discounted environmental values provide more an uncertain digest of partial information than a basis for well-informed efficiency evaluation.

The literature on hyperbolic discounting is potentially fatal to the DU (Ramsey) approach to discounting the future, which assumes that society acts (or should act) like a single, self-regarding, optimizing, infinitely lived agent. We argue above that how individuals value tradeoffs between their own present and future well-being is conceptually disjoint from the question of how social decisions about the future should be made.

In the DU framework, the social good is maximized by decisions of isolated individuals making selfish choices in competitive markets. This framework has been consciously used to dismiss any sort of cooperative, collective public policy. Bromley (2007, p. 677) is critical of the takeover of reasoned public discourse and democratically chosen public policies by the individual-acting-in-the-market mentality: "It is a quest for public policy in which applied micro-economics is deployed as the only way to impose 'rationality' on an otherwise incoherent and quite untrustworthy political process." Effective social and economic policies require drawing upon aspects of human nature emphasizing cooperation, non-market values, and a shared sense of responsibility. Greed and accumulation are only a part of the richness of human behavioral patterns. Types of behavior conducive to

cooperation, doing with fewer material possessions, and recognizing the necessity of shared sacrifice, are also part of the human experience and these behaviors should certainly be taken into account in any intergenerational policy decisions.

REFERENCES

ACKERMAN Frank and HEINZERLING Lisa (2004), Priceless: On Knowing the Price of Everything and the Value of Nothing.

AINSLIE G. (1974), "Impulse control in pigeons", *Journal of the Experimental Analysis of Behavior*, N.21, pp.485–489.

AINSLIE George (2005), "Précis of breakdown of will", *Behavioral and Brain Sciences*, N.28, pp.635-673.

ALBIN P.S. (1975), "Reswitching: an empirical observation, a theoretical note, and an environmental conjecture", *Kyklos*, N.28, pp.149–153.

ALBRECHT A. and WEBER M. (1995), "Hyperbolic discounting models is prescriptive theory of intertemporal choice", *Zeitschrift für Wirtschafts- und Sozialwissenschaftten*, N.115, pp.535–568.

ALLMAN John M., WATSON Karli K., TETREAULT Nicole A. and HAKEEM Atiya Y. (2005), "Intuition and autism: a possible role for Von Economo neurons", *TRENDS in Cognitive Sciences*, Vol.9, N.8, pp.367-373.

ARROW K., DASGUPTA P., GOULDER L., DAILY G., EHRLICH P., HEAL G., LEVIN S., MALER K.-G., SCHNEIDER S., STARRETT D., and WALKER B. (2004), "Are we consuming too much?", *Journal of Economic Perspectives*, N.18, Iss.3, pp.147–172.

ASHEIM G.B. (2008), "The occurrence of paradoxical behaviour in a model where economic activity has environmental effects", *Journal of Economic Behaviour and Organization*, N.65, pp.529–546.

BARBIER E. (2007), "Valuing ecosystem services", *Economic Policy*, pp.177–229.

BAUMOL W.J. (1968), "On the social rate of discount", *American Economic Review*, N.58, pp.788–802.

BELLOS Alex (2010), Here's Looking at Euclid, Free Press.

BRADSHAW C., SZABADI E., and BEVAN P. (1976), "Behavior of humans in variable-interval schedules of reinforcement", *Journal of the Experimental Analysis of Behavior*, N.26, pp.135–141.

BROMLEY Daniel W. (1990), "The ideology of Efficiency: Searching for a Theory of Policy Analysis, *Journal of Environmental Economics and Management*, N.19, pp.86-107.

BROMLEY Daniel W. (2006), Sufficient reason: volitional pragmatism and the meaning of economic institutions, Princeton University Press.

BROMLEY Daniel W. (2007), "Environmental regulations and the problem of sustainability: moving beyond market failure", *Ecological Economics*, N.63, pp.676–683.

CAINES J. and VAN DER POL M. (2000), "Valuing future private and social benefits: the discounted utility model versus hyperbolic discounting models", *Journal of Economic Psychology*, N.21, pp.191–205.

CARSON R. and ROTH Tran B. (2009), "Discounting behavior and environmental decisions", *Journal of Neuroscience, Psychology, and Economics*, N.2, pp.112–130.

CASS D. (1965), "Optimum growth in an aggregative model of capital accumulation", *Review of Economic Studies*, N.32, pp.233–240.

CHICHILNISKY G., HEAL G. and BELTRATTI A. (1995), "The green golden rule", *Economics Letters*, N.49, pp.175–179.

CLARK C. (1990), Mathematical Bioeconomics, John Wiley, New York.

COLE D. (2008), "The Stern Review and its critics: implications for the theory and practice of benefit–cost analysis", *Natural Resources Journal*, N.48, 53–90.

CROPPER M. and LAIBSON, D. (1999), "The implications of hyperbolic discounting for project evaluation" In: PORTNEY P. and WEYANT J. (Eds.), Discounting and Intergenerational Equity. Resources for the Future, Washington, DC (Chapter 16).

DASGUPTA P. and HEAL G. (1974), "The optimal depletion of exhaustible resources", *The Review of Economic Studies Symposium Issue*, pp.3–28.

DING P., GERST M., BERNSTEIN A., HOWARTH R. and BORSUK M. (2012), "Rare disasters and risk attitudes: international differences and implications for integrated assessment modelling", *Risk Analysis*, N.32, pp.1846–1855, http://dx.doi.org/10.1111/j.1539-6924.2012.01872.x.

ESTLE Sara J., COHEN Leonard, MYERSON Joel and HOLT Daniel D. (2007), "Discounting of Monetary and Directly Consumable Rewards", *Psychological Science*, Vol.18, N.1, pp.58-63.

FANTINO E. (1998), "Behavior analysis and decision making", *Journal of the Experimental Analysis of Behavior*, N.69, pp.355–364.

FARZIN Y.H. (1984), "The effect of the discount rate on depletion of exhaustible resources", *Journal of Political Economy*, N.92, pp.841–851.

FISHER A.C. (1981), Resource and Environmental Economics. Cambridge University Press, Cambridge, UK.

FISHER I. (1930), The Theory of Interest. Augustus M. Kelly, New York.

FISKE Alan Page and TETLOCK Philip E. (1997), "Taboo trade-offs: reactions to transactions that transgress the spheres of justice", *Political psychology*, Vol.18, N.2, pp.255-297.

FREDERICK Shane, LOEWENSTEIN George and O'DONOGHUE Ted (2002), « Time discounting and time preference: a critical review », *Journal of Economic Literature*, Vol.XL, pp.351-401.

GINTIS H. (2006), "Cultural Darwinism", *Boston Review* http://bostonreview.net/BR23.1/Gintis/html

GOWDY John (1997), « The value of biodiversity: markets, society, and ecosystems », *Land Economics*, Vol.73, No.1, pp.25-41.

GOWDY J. (2000), "Terms and concepts in ecological economics", *Wildlife Society Bulletin*, N.28, pp.26–33.

GOWDY John, HOWARTH Richard B. and TISDELL Clem Tisdell (2010), "Discounting, ethics, and options for maintaining biodiversity and ecosystem integrity", Chapter 6 in TEEB (2010), The Economics of Ecosystems and Biodiversity: Ecological and Economics Foundations, Ed. Pushpam KUMAR, Earthscan, London and Washington.

GOWDY, J. and PARKS S. (2013), "Behavioral arguments for deliberative valuation". In: KUMAR P. and NUNES P. (Eds.), Ecosystems and Biodiversity. Edward Elgar, Cheltenham, UK.

GRAAFF J .de V. (1987), "Social cost", in: EATWELL J., MILGATE M., NEWMAN P. (Eds.), The New Palgrave Dictionary of Economics, vol. 4. Macmillan, London, pp. 393–395.

GREEN L., MYERSON J. (1996), "Exponential versus hyperbolic discounting of delayed outcomes: risk and waiting times", *American Zoologist*, N.36, pp.496–505.

GREEN L., MYERSON J., and CALVERT A. (2010), "Pigeons' discounting of probabilistic and delayed reinforcers", *Journal of the Experimental Analysis of Behavior*, N.94, pp.113–123.

GRUBER J. (2007), Public Finance and Public Policy. Worth, New York (Chapter 8).

HANNESSON R. (1987), "The effect of the discount rate on the optimal exploitation of a renewable resource", *Marine Resource Economics*, N.3, pp.319–329.

HARCOURT G.C. (1972), Some Cambridge Controversies in the Theory of Capital, Cambridge University Press, Cambridge, UK.

HARPER D. (1982), "Competitive foraging in mallards: ideal free ducks", *Animal Behavior*, pp.30–584.

HARVEY C. (1986), "Value functions for infinite period planning", *Management Science*, N.32, pp.1123–1139.

HAUSMAN J. (1979), "Individual discount rates and the purchase and utilization of energy using durables", *Bell Journal of Economics*, N.10, pp.33–54.

HENRICH N. and HENRICH J. (2007), Why Humans Cooperate: A Cultural and Evolutionary Explanation. Oxford University Press, Oxford, UK.

HEPBURN C., KOUNDOURI P., PANOPOULOU E., and PANTELIDIS T. (2009), "Social discounting under uncertainty: a cross-country comparison", *Journal of Environmental Economics and Management*, N.57, pp.140–150.

HERFINDAHL O.C. and KNEESE A.V. (1974), Economic Theory of Natural Resources, Charles Merrill, Columbus, OH.

HERRNSTEIN R. (1961), "Relative and absolute strength of responses as a function of frequency of reinforcement", *Journal of the Experimental Analysis of Behavior*, N.4, pp.267–272.

HILL K., WALKER R., BOZICEVI M., ELDER J., HEADLAND T., HEWLETT B., HURTADO M., MARLOWE F., WIESSNER P., Wood, B. (2011), "Co-residence patterns in hunter-gatherer societies show unique human social structure, *Science*, N.331, p.1286.

HOWARTH R. (2009), "Rethinking the theory of discounting and revealed time preference", *Land Economics*, N.85, pp.24–40.

HOWARTH R. and SANSTAD A.H. (1995), "Discount rates and energy efficiency", *Contemporary Economic Policy*, N.13, pp.101–109.

HOWARTH R. and WILSON M. (2006), "A theoretical approach to deliberative valuation: aggregation by mutual consent", *Land Economics*, N.82, pp.1–16.

JENSEN K., CALL J. and TOMASELLO M. (2007), "Chimpanzees are rational maximizers in the ultimatum game", *Science*, N.318, pp.107–109.

JIMURA K., MYERSON J., HILGARD J., BRAVER T., and GREEN L. (2009), "Are people really more patient than other animals? Evidence from human discounting of real liquid rewards", *Psychonomic Bulletin & Review*, N.16, pp.1071–1075.

KIM B., ZAUBERMAN G. (2009), "Perception of anticipatory time in temporal discounting", *Journal of Neuroscience, Psychology, and Economics*, N.2, pp.91–101.

KIRBY K. (1997), "Bidding on the future: evidence against normative discounting of delayed rewards", *Journal of Experimental Psychology: General*, N.126, pp.54–70.

KOOPMANS T.C. (1960), "Stationary ordinal utility and impatience", *Econometrica*, N.28, pp.287–309.

KOOPMANS T.C. (1965), "On the concept of optimal economic growth", Pontifica Academia delle scienze In: Study Week on the Econometric Approach to Development Planning, North-Holland, Amsterdam.

LAIBSON D. (1997), "Golden eggs and hyperbolic discounting", *Quarterly Journal of Economics*, N.112, pp.443–477.

LOEWENSTEIN G., PRELEC D. (1992), "Anomalies in intertemporal choice: evidence and an interpretation", *Quarterly Journal of Economics*, N.107, pp.573–597.

LUDWIG D., BROCK W., CARPENTER S. (2005), *Ecology and Society*, N.10, Iss.2, http://www.ecologyandsociety.org/vol10/iss2/art13/

MALER K.-G. (1985), "Welfare economics and the environment", in: KNEESE A.V., SWEENEY J.L. (Eds.), Handbook of Natural Resource and Energy Economics, North-Holland, Amsterdam.

MARGLIN S.A. (1963), "The social rate of discount and the optimal rate of investment", *Quarterly Journal of Economics*, N.77, pp.95–111.

MAZUR J. (1987), "Tests of an equivalence rule for fixed and variable reinforce delays", *Journal of Experimental Psychology*, N.10, pp.426–436.

MCLURE S., LAIBSON D., LOWENSTEIN G. and COHEN J. (2004), "Separate neural systems value immediate and delayed monetary rewards", *Science*, N.306, pp.503–507.

MCCOMB K., PACKER C. and PUSEY A. (1994), "Roaring and numerical assessment in contests between groups of female lions, Pantheraleo", *Animal Behavior*, N.47, pp.379–387.

NEWELL R. and PIZER B. (2003), "Discounting the distant future: how much do uncertain rates increase valuations?", *Journal of Environmental Economics and Management*, N.46, pp.52–71.

NORDHAUS W. and BOYER J. (2000), Warming the World: Economic Models of Global Warming, MIT Press, Cambridge, MA.

NOWAK M. and HIGHFIELD R. (2011), Super Cooperators: Altruism, Evolution, and Why We Need Each Other to Succeed, Free Press, New York.

PANNELL D. and SCHILIZZI S. (Eds.) (2006), Economics and the Future, Edward Elgar, Cheltenham, UK.

PEARCE D., GROOM B., HEPBURN C. and KOUNDOURI P. (2003), "Valuing the future: recent advances in social discounting", *World Economics*, N.4, pp.121–141.

PHELPS E. and POLLAK R. (1968), "On second-best national saving and game-equilibrium growth", *Review of Economic Studies*, N.35, pp.201–208.

PHILIBERT Cédric (1999), « The economics of climate change and the theory of discounting », *Energy Policy*, N.27, pp.913-927.

PHILIBERT C. (2006), "Discounting the future" in: PANNELL D. and SCHILIZZI S. (Eds.), Economics and the Future, Edward Elgar, Cheltenham, UK.

PICA Pierre, LEMER Cathy, IZARD Véronique and DEHAENEAL Stanislas (2004), "Exact and Approximate Arithmetic in an Amazonian Indigene Group", *Science*, Vol.306.

PORTER R.C. (1982), "The new approach to wilderness through benefit cost analysis", *Journal of Environmental Economics and Management*, N.9, pp.59–80.

PRINCE R., ROSSER Jr. J.B. (1985), "Some implications of delayed environmental costs for benefit cost analysis: a study of reswitching in the western coal lands", *Growth and Change*, N.16, pp.18–25.

QUIGGIN J. (2008), "Stern and the critics on discounting and climate change: an editorial essay", *Climatic Change*, N.89, pp.195–205.

RAMSEY F. (1928), "A mathematical theory of saving", *Economic Journal*, N.38, pp.543–549.

RICHERSON P. and BOYD R. (2005), Not by Genes Alone: How Culture Transformed Human Evolution, University of Chicago Press, Chicago.

ROBERTS W. (2002), "Are animals stuck in time?", *Psychological Bulletin*, N.128, Iss.3, pp.473–489.

ROSATI A., STEVENS J., HARE B. and HAUSER M. (2007), "The evolutionary origins of human patience: temporal preferences in chimpanzees, bonobos, and human adults", *Current Biology*, N.17, pp.1663–1668.

RUBINSTEIN A. (2003), “Economics and psychology? The case of hyperbolic discounting”, *International Economic Review*, N.44, pp.1207–1216.

SAGOFF M. (1994), “Should preferences count?”, *Land Economics*, N.70, pp.144–170.

SAMUELSON P.A. (1937), “A note on measurement of utility”, *Review of Economic Studies*, N.4, pp.155–161.

SCHELLING T. (1995), “Intergenerational discounting”, *Energy Policy*, N.23, pp.395–401.

SCHMIDT C. (2010), Neuroéconomie, Odile Jacob, Paris.

SETTLE C. and SHROGEN J. (2004), “Hyperbolic discounting and time inconsistency in a native exotic species conflict”, *Resource and Energy Economics*, N.26, pp.255–274.

SHERWOOD C., SUBIAUL F., ZADISZKI T. (2008), “A natural history of the human mind: tracing evolutionary changes in brain and cognition”, *Journal of Anatomy*, N.212, pp.426–454.

SOBER E. and WILSON D.S. (1998), Unto Others: The Evolution and Psychology of Unselfish Behavior, Harvard University Press, Cambridge, MA.

SRAFFA P. (1960), Production of Commodities by Means of Commodities: A Prelude to a Critique of Economic Theory. Cambridge University Press, Cambridge, UK.

STERN N. (2007), The Economics of Climate Change: The Stern Review, Cambridge University Press, Cambridge, UK.

STIEGLER R. and BOOTH J. (2004), “Development of numerical estimation in young children”, *Child Development*, N.75, pp.428–444.

STOCKFISH J.A. (1969), Measuring the Opportunity Cost of Government Investments, Institute for Defense Analysis, Washington, DC.

STROTZ R. (1956), “Myopia and inconsistency in dynamic utility maximization”, *Review of Economic Studies*, N.23, pp.165–180.

THALER R. (1981), “Some empirical evidence on dynamic inconsistency”, *Economic Letters*, N.8, pp.201–207.

TINBERGEN N. (1963), “On aims and methods in ethology”, *Zeitschrift für Tierpsychologie*, N.20, pp.410–433.

TISDELL C. (2005), Economics of Environmental Conservation, 2nd edition. Edward Elgar, Cheltenham, UK.

TRAIN K. (1985), “Discount rates in consumer’ energy related decisions: a review of the literature”, *Energy*, N.10, pp.1243–1253.

WEITZMAN Martin L. (2001), “Gamma discounting“, *American Economic Review*, Vol.91, N.1, pp.260-271.

WEXLER B.E. (2006), Brain and Culture, MIT Press, Cambridge, MA.

WILSON David S. and GOWDY John (2010), “The Relevance of Evolutionary Science For Economic Theory and Policy”, White paper for NSF SBE Program Initiative “Framing Research for 2020 and Beyond”.

WINKLER R. (2006), “Does ‘better’ discounting lead to ‘worse’ outcomes in long-run decisions? The dilemma of hyperbolic discounting”, *Ecological Economics*, N.57, pp.573–582.

WITTMANN M. and PAULUS M. (2009), “Intertemporal choice: neuronal and psychological determinants of economic decisions”, *Journal of Neuroscience, Psychology, and Economics*, N.2, pp.71–74.

WOOLLEY A., CHABRIS C., PENTLAND A., HASHMI M. and MALONE T. (2010), “Evidence for a collective intelligence factor in the performance of human groups”, *Science*, N.330, pp.686–688.

ESSAY 4. On the relevance for public decision makers of traditional monetary valuations applied to biodiversity

Abstract

There is an overwhelming literature on environmental evaluations and valuations (Champ et al., 2003), and the literature on biodiversity valuations is quickly expending. However, existing tools to measure and manage biodiversity do not yet satisfy simultaneously methodological, ethical, and pragmatic criteria (Scherrer, 2004). Fundamentally, valuing biodiversity is a real challenge (Meinard and Grill, 2011). Biodiversity is the diversity of living and not the living itself or its biological resources (Maris and Reveret, 2009; Nunes and Van den Bergh, 2001). In addition, biodiversity losses are so important and spread geographically (and temporally) that they result in value conflicts that require to be dealt with by ethical considerations and not only technical one. This article tries therefore to highlight some conceptual limits of the traditional (neoclassical) valuation methods when applied to biodiversity (methodological and ethical analysis), and to discuss the relevance of those methods for public decision makers (pragmatic analysis). Concretely, we first define the object biodiversity and discuss its economic status, before synthetizing the foundations of the neoclassical economic theory of value and the main valuations methods. We ultimately confront those points, emphasize the dimensions of biodiversity that monetary valuations cover and do not cover, and highlight some strengths and weaknesses of those valuations regarding their relevance for public decision markers.

4.1. Introduction

The notion biodiversity, or biological diversity, refers to the diversity of the living. It refers at least to the diversity of organizational levels existing and the corresponding biological objects (Weesie and Van Andel, 2003), but often it refers also to the diversity of

interactions[71][72], processes and functions taking place within the living world (Angermeier and Karr, 1994)[73]. We will call the first type of diversity the diversity of objects (DO), and the second type of diversity the diversity of processes (DP). Two precisions are required. First, the diversity of organizational levels and biological objects (DO) refers itself to two kinds of diversity, the diversity among those levels and objects, and the diversity within those levels and objects. The DO can be apprehended at multiple different levels, even though it is often the case that only the genetic, specific and ecosystemic levels are considered. Among the organizational levels and biological objects that can be considered rank alleles, genes, chromosomes, genotypes, individuals, populations, species, communities, ecosystems, landscapes, ecoregions, biomes and finally, the biosphere as a whole (Weesie and Van Andel, 2003). Second, biological diversity does not strictly refer to the diversity of living things but to the diversity of the living word. Nature is a functioning system thanks to biotic and abiotic elements, and so when we deal with biodiversity, in particular with the diversity of interactions, processes and functions involving living entities (DP involving DO), abiotic elements are necessary involved. This is why we can speak for instance about the diversity of ecosystems as one level of biodiversity, even though ecosystems are not only composed of biotic elements.

Biodiversity appears therefore as a very complex object, not just to study but already to conceptualize. Philosopher Maris (2010) suggests seeing biodiversity as a property and as a process. This terminology emphasizes the fact that biodiversity as a whole refers to an established existing dimension (the property, i.e. the property to be diverse) and to a dynamic dimension (the process, i.e. the diversity in action and the diversity of actions). We may think that the DO correspond to biodiversity-as-a-property and the DP correspond to biodiversity-as-a-process, but actually, the DP can actually be seen as a property while the DO are obviously involved, with the DP, in the process. This complexity results from the fact that biodiversity is in constant evolution, and while it is characterized by certain diversity at a given point of time (property), this property is also constantly evolving (process). Indeed, biodiversity can be seen as prerequisite and as a result of evolution and so as means and as ends (Potthast, 1996). So those two dimensions of biodiversity (property and process)

[71] Organisms interact between themselves and with their changing environment (Ehrlich and Ehrlich, 1992).
[72] It is the network of interactions between organisms that breathes life into ecosystems, and not the diversity per se [i.e. the diversity of levels and objects] (McCann, 2000)
[73] By assuming that diversity refers to processes and not just to property, we may have more or less assumed that biodiversity resume biological integrity. This is a potential limit to be analysed and overcome in further research.

influence therefore each other and co-exist, which makes the overall biodiversity a sort of systemic entity, i.e. a global system of relations between process and states variables (Godard, 2005).

We are not only interested in this article in what biodiversity is, but also in what biodiversity does for nature and humans (we will come to that soon), and in the value attributed by humans to this "existence" and those contributions. To understand what biodiversity does, we need to consider biodiversity as a property (DP providing a diversity of natural services and DO providing a diversity of resources), biodiversity as a process (DP and DO allowing biodiversity's own functioning) and but also biodiversity's role in nature's own functioning and capacities. Only after that can we try to get a sense of the importance and value of biodiversity. Indeed, the contribution of biodiversity to nature's functioning are often regarded and highlighted as the most urgent reason justifying its preservation in natural sciences. Among others, we find in the literature mentions of biodiversity's contributions to the capacities to function, to be stable, to be less vulnerable and adapt, to be resilient, to have a maintained integrity, and to have an evolution and an evolutionary potential. However, we already saw that it is necessary to take into account abiotic elements when we deal with biodiversity; that makes the distinction between the functioning of biodiversity, the functioning of nature and the contribution of biodiversity to nature difficult. In addition, the scientific knowledge about biodiversity and nature[74] and about the contribution of biodiversity to nature's functioning and capacities, is limited[75] and uncertain. So we will refer in this article to the general functional dimension of biodiversity, understood as the combination of biodiversity as a process and the functional role of biodiversity in nature, and we will assume that the general idea is that nature functions better when it is diverse[76].

[74] "Uncertainty refers to the situation in which there is not a unique and complete understanding of the system to be managed" (Brugnach et al., 2008 in Barnaud et al., 2011).
[75] The correlations between the different levels of biodiversity and nature's capacities are not all straightforward, clear or even understood at all (Weesie and Van Andel, 2003). Drastically alternatives hypothesis coexist; for instance the redundant species hypothesis which assumes that ecosystem functioning is mainly regulated by a few dominant species and that most co-occurring species are redundant; and the rivet hypothesis that assumes that every species is of (almost) equal importance for the functioning of the ecosystem they live in (Weesie and Van Andel, 2003). Numerous gaps exist in our knowledge of biodiversity role in nature's capacities, but they also exist in our understanding of nature's capacities themselves (Amara, 2010). "Our level of knowledge of the contents and the metabolism of natural systems is simply too low." (Dumont, 2005).
[76] We observe that natural systems functions better when they are diverse, and particularly when they have a high specific diversity (Cardinale et al., 2006; Hooper et al., 2005 in Meinard and Grill, 2011).

To summarize, biodiversity refers to the inter - and intra - diversity of organizational levels and the corresponding biological objects (DO), and to the diversity of interactions, processes and functions taking place within the living world (DP). It can be seen as a property and a process, and as a systemic entity that has its own functioning and that contributes to the well-functioning and capacities of nature. Biodiversity has therefore a functional dimension in addition to being a property.

4.2. The economic status of biodiversity

We will now start investigating how in this context of complexity and uncertainty, economics should deal with biodiversity, and what kind of object can biodiversity be for economics? Biodiversity can obviously be seen as an attribute of a good (for instance the specific and genetic diversity of fauna and flora of a site), and can therefore be studied by the branch of economic literature that deals with goods' attributes[77]. But this approach focuses only on biodiversity as a property. Biodiversity has been handled as a good and as marketed good and services (Spash and Hanley, 1995) or commodities (Gowdy, 1997). Many studies have focused on natural resources, which are manifestations of biodiversity (Nunes and Van den Bergh, 2001) rather than on biodiversity per se (Beaumont et al, 2008). But actually biodiversity is not a good (Godard, 2005), because a good is an entity that can be physically isolated (Walliser and Prou, 1988 in Godard, 2005[78]) and while we can isolate one species and observe its genetic diversity, we are not isolating physically the diversity per se.

Different authors have focused on different levels of diversity, the genetic diversity of species (Weitzman, 1998; Simpson, Sedjo and Reid, 1996) or the specific diversity (Ando et al., 1998; Bishop, 1978; Kassar and Lasserre, 2004), but again they often focus on biodiversity-as-a-property. What about the functional dimension of biodiversity (Maris, 2010))? The assimilative capacity of the environment and ecological life support systems have been sometimes classified among semi renewables resources (Barbier and Markandya, 1990). While this is again reducing (and mixing) a property of those resources and the causes/necessary conditions of the existence of those resources to (with) the resources

[77] Attribute-based valuation methods, pioneered by Gorman (1956) and Lancaster (1966), which commodities in terms of their characteristics, i.e. various desirable properties (Sen, 1999).

themselves, such an approach takes into account some dynamics, i.e. the fact that biodiversity regenerates itself (is renewable) and also evolves and adapts itself (the new state of biodiversity is different from the old state, which makes the old state of biodiversity non-renewable).

The notion of biodiversity has been formally analyzed by axiomatic economists (Meinard and Grill, 2011), such as Nehring and Puppe (2002) or Weitzman (1992), and it is predominantly understood as specific diversity or the genetic diversity of species[79]. While those approaches focus at least on diversity (the diversity of species or genes) and not on the species themselves, they leave again some dimensions of biodiversity behind, especially the functional dimension. Is economics lacking words to describe biodiversity, as Godard (2005) wonders? For Meinard and Grill (2011), biodiversity is an abstract concept, used to ask broad questions pertaining to ecological theory, associated practices (e.g. conservation management and policies) and their ultimate significance[80], which cannot exist on its own and cannot be identified without observing and interpreting a wide variety of relevant objects. This approach tends to be holistic rather than reductionist, as the holistic perspective of biodiversity sees biodiversity as an abstract notion linked to the integrity, stability and resilience of complex systems, difficult to disentangle (Faber et al., 1996 in Nunes and Van den Bergh, 2001). Meinard and Grill (2011) also suggest studying relevant objects to biodiversity in order to grasp some of its nature, but this is not reductionist insofar as it does not assume that biodiversity is the sum of those objects but only that those objects are relevant.

So holistic (biodiversity cannot be decomposed) and reductionist (biodiversity can be decomposed) approaches to biodiversity exist. The importance given to the functional dimension of biodiversity by different fields of research is obviously one of the factors explaining such difference in approach. Economics, not studying the functioning of nature, is easily reductionist, and we see the functional dimension of biodiversity as one of the many stumbling blocks existing between economists and natural scientists when they debate about biodiversity's value. Indeed, we can briefly refer to a few notions related to the functional dimension of biodiversity to realize how tension can arise between ecological and human interests. The contribution of biodiversity to nature's functioning itself is not the most

[79] They adopt a multi-attribute approach to it, considering the aggregate dissimilarity between species as a measure of diversity.
[80] Goods existing thanks to biodiversity do not carry the overall issue raised by biodiversity (Godard, 2005).

contentious notion because it can stay vague and "satisfies" what we will schematically call ecological and direct human interests. Biological diversity helps nature functioning and it also provides a diversity of goods and services for humans. However, it is also shown that natural systems can also be more stable and productive (Worm et al., 2006) when they have a high specific diversity. Productivity satisfied again both interests, but stability can be defined as a system's dynamic stability, or a system's ability to defy change and therefore ability to be resilient and resistant (McCann, 2000). We may desire that natural systems adapt and are less vulnerable to changes but we may also desire that they stay as much as possible the same, because we are ourselves adapted to- and beneficiary of- their current state. The notion that may raise the most tensions is still the evolutionary capacity of nature. As the economists Pearce and Moran (1994) put it, "can we be concerned with the perversion of the evolutionary processes as opposed to the immediacy of system thresholds and flips?" For some authors, we have an "evolutionary responsibility" (Potthast, 1996) and therefore we should care about the role of biodiversity in maintaining a life support system and an evolutionary potential (Gowdy, 1997; Thompson, 2010). But this may be hard to translate in economic terms, and may introduce conflicts between long-term ecological issues and shorter-term economic issues.

We have mentioned already several times economics, but without clearly defining the goal of the economic analysis, and particularly of the economic analysis of biodiversity. Since Rio 1992 conference, nature has become biodiversity (Fleury and Prévot-Juliard, 2012), and biodiversity has become the threatened biological diversity (Maris, 2010). Many researchers (in all disciplines) have therefore worked on "biodiversity" in order to develop or improve ways to prevent biodiversity losses, and so biodiversity has been dealt with via the study of particular biodiversity losses, i.e. changes in biodiversity. Depending on their own environmental ethics and their disciplines, authors' actual focus may have been on biodiversity losses themselves or rather on the consequences of biodiversity losses for human societies.

We discussed in the article 2 the nature of the ethical approach that economics adopt toward the world, and more particularly toward nature and biodiversity. It is anthropocentric (i.e. it considers only humans values (Norton, 2003)) and it is instrumental (it is interested in how nature can be used by humans *and* in what it can do for people including though experiencing

nature), without necessarily being strongly anthropocentric or merely instrumental. So economics definitely cares about the consequences of biodiversity for human societies. If we assume that humans can care about biodiversity losses independently of any human uses, experiences or satisfaction, then economics will care about those biodiversity losses indirectly by taking into account humans' concerns. However, we will not argue here that humans are capable of such concern free of reference to their own need or satisfaction (even desiring that some ecosystem or species outlive the human race can be related to some satisfaction it procures to be environmentally concerned). This still leave place for a wide range of human values to be taken into account by economics. If we further consider economics as the science that studies human system of provisioning (Bromley, 2006), then the consequences of biodiversity losses on human societies, for economics, have to do with changes in the human provisioning systems resulting from biodiversity losses, which are valued by humans. We understand here very broadly the notion of provisions; they include material and non-material provisions, i.e. natural resources but also nice scenery of instance. This is justified by the fact that some provisions are entirely human-made and obviously part of the provisioning systems, but other provisions exist, that are naturally made, influenced by human activities (positively, see agriculture using the potential of earth to grow food for instance, or negatively, see trawling destroying marine landscapes) and enjoyed by humans sufficiently to consider those provisions part of the provisioning system as well.

Does it mean that economics adopt a reductionist approach to biodiversity? Economics is concerned with the consequences of biodiversity losses on the provisions involved in human provisioning systems but also with the consequences of biodiversity losses on the natural processes and conditions that insure the supply of those provisions. This requires to take into account the functional dimension of biodiversity, and it may require economics not to adopt a reductionist approach because we cannot apprehend functioning systems only by their components, as a functioning system is more that its components (Brauër, 2003)[81]. And so economists are advised to approach biodiversity as a highly complex system under uncertainty (Bishop, 1978; Heal, 2004). They are not asked to study the functioning itself (task of natural sciences) but rather not to reduce biodiversity to its components, and to see those components are 'functioning part' (Ehrlich and Ehrlich, 1992) of biodiversity and nature.

[81] "It is the underlying architecture, not just the parts by themselves, that maintains the bodily functions necessary for life" (McCann, 2000).

We will move forward and address the issue of the monetary economic value of biodiversity. Biodiversity is obviously recognized as an object of major economic value, as a property, but also for its functional dimension. It contributes to the viability of certain essential ecological processes and circumstances (Bromley, 1998) that are in turn necessary for human societies to properly function, for human wellbeing to be secured (Naeem et al., 2009 in Meinard and Grill, 2011). However, does it not mean that economics can and should value monetarily all those contributions of biodiversity? To discuss this point, we will now introduce the mainstream, i.e. neoclassical (Pearce and Turner, 1990)/welfare (Gowdy, 2010) theory of economic value. We will investigate the components of this economic value, and the different monetary values that have been attributed to 'biodiversity' and its surrogates. This will help us to identify the economic status that biodiversity has in the particular context of monetary valuations, and to confront it with the analysis we just developed.

4.3. The theory of the economic valuation of biodiversity

4.3.1. The theory of economic values

Before analyzing critically this theory in section 4.4, we quickly resume it. A thing has some *economic value* if individuals derive utility from it, and we can estimate this utility by observing individuals' behavior (revealed preference methods, see next section) or by asking individuals about it (stated preference methods, see next section). Therefore, the economic value derived from this approach is necessarily based on subjective preferences. In addition, this is a marginal theory of value, i.e. it is based on the measure of the value of an incremental unit (for quantity or price) or degree (for quality) of a good. It is based on the measure of changes in utility, but it can be used to estimate total utility derived from a good, as long as all the satisfaction components to the total satisfaction can actually be considered as marginal. One can easily see how the glass of water after an agonizing thirst would provide more than a marginal satisfaction and rather an infinite satisfaction to an individual as it saves him.

Prices and valuations are two ways of estimating, not the economic value per se, but some *monetary values* of goods, and there are based on a marginal approach value. Prices provide a

measure of the *market exchange value* of objects, and so a signal about the economic scarcity of the good (Pearce and Turner, 1990), i.e. the tension between supply and demand as prices result from the confrontation of demand and supply on markets. Because the consumer has to choose between different consumption goods, prices also reflect the relative market exchange value of goods ("relative prices"), i.e. the exchange value of a commodity relative to the value of other market commodities available to individual consumers at a specific point in time (Gowdy, 1997). The marginal foundation of prices is found in the demand and supply functions of economic agents, because those represent the marginal prices that consumers and producers are ready to pay/to accept for each incremental unit of the good.

This makes the demand function being a marginal Willingness-To-Pay (WTP) curve. The neoclassical theory of economic value is fundamentally based on the idea that individuals act in ways that maximizes their utility, and so that their actions or sayings reveal their preferences, i.e. the situation that brings them the most satisfaction and that is therefore preferred. A preference for something will show up (either in acts, revealed preferences, or in words, stated preferences) in the form of a willingness to pay for it (Pearce and Turner, 1990), which can be higher than the market price. This is why the economic value (the total satisfaction derived from consuming or enjoying a good by individuals) of a good is worth more than the exchange value of a good (demand function integrates individual preferences but the confrontation of demand and supply functions ultimately reveal a state of scarcity rather people's valuation of the good). And so to estimate the economic value of good, in this theory, we need to know the total WTP of individuals for the good, i.e. to have a demand curve for the good[82]. However, this can be difficult or even impossible for some environmental goods.

As for monetary valuations, they are either made with some monetary proxy such as prices[83] or costs, or with the Willingness-To-Pay (WTP) for - or the Willingness-To-Accept (WTA) - a marginal change in quantity, price or quality of an object. There are numerous and can adopt fundamentally different approaches and assumptions to value estimations, as we will see

[82] It is possible to use information about individuals' preferences and income constraint to estimate individuals demand, and it is possible to use information about individuals' demand to obtain information about their preferences (Varian, 2009).
[83] Price-based methods are those using some existing market prices (TEEB, 2010) whether there are efficient or distorted (Markandya et al., 2001).

soon. What we will ultimately try to understand about those methods, is the type of value they estimate.

We can now introduce the neoclassic analysis of the nature of the economic values embodied in the demand curve (Pearce and Turner, 1990), i.e. in individuals' preferences (their subjective individual valuation of biodiversity can be decomposed following a reductionist approach). The economic value is indeed composed of several types of economic values. The Total Economic Value (TEV) approach of a good decomposes this economic value into use and non-use (or passive use) values (Pearce et al., 2006), or even more often into use, non-use and option values because the option value is a complex and debated value to classify. There is however no agreement on the nature of the equation for total economic value (Pearce and Turner, 1990), and even on the exact nature of the different values included.

While use values (direct or indirect) correspond to the valuations of clear uses that are made of nature/biodiversity by humans, non-uses values refer to more complex values. They include at least the existence, the legacy/bequest and the altruist values (TEEB, 2010). However, the legacy and the altruist values actually refer to some uses, i.e. to the potential uses that could be made of biodiversity by others individuals than the individuals actually involved in the valuation process. The legacy value refers to the satisfaction felt by the valuators that some uses of biodiversity should be made in the future by next generations, and the altruist value refers to the valuators' satisfaction that other contemporary societies can use biodiversity (TEEB, 2010). This is why those two values have also been ranked under the passive use values category. The existence value is a more fuzzy value (Pearce and Turner, 1990), whose definition is broadly the "satisfaction of knowing that a species or ecosystem exists" felt by individuals (TEEB, 2010). It is more or less assumed that the existence value stands for the intrinsic value of the good (Pearce and Turner, 1990) and so resumes it, even though there are at least three definitions of this value as we saw in article 2, quite different from the definition of the existence value, and with one among them that is incompatible with the idea that individuals can attribute some intrinsic value to the good because the intrinsic value of a good is independent of the valuation of valuators (O'Neill, 2003). Finally, the option value (Weisbrod, 1964) refers to the value that humans attribute to keeping the options of benefiting from some aspects of biodiversity, like keeping the option of consuming some

resources or the option of visiting a natural site (indeed, the value of a site cannot be resumed by the cost of entry as individuals not visiting the site may value the site and having the option of visiting the site one day). Those options can potentially disappear for humans as a result of biodiversity losses, especially in the case of irreversible biodiversity losses (which can represent a significant part of biodiversity losses).

As the TEV can be decomposed, it is often assumed that a range of valuation methodologies can be applied and capture different components of the TEV (Ledoux and Turner, 2002). For instance and according to TEEB (2010), use values can be valued by market analysis, cost methods, production function, hedonic pricing, contingent valuation; option or quasi-option value can be valued by replacement cost method, mitigation cost method, and avoided cost method and non-use value can be valued by contingent valuation. We will see that those methods adopt different fundamentally different approaches to valuations.

4.3.2. The foundations of the environmental monetary valuations methods

For our analysis, we need the two following tables. The first reviews some of the usual monetary valuations methods; the second introduces their basic approach to valuation.

Figure 22: common monetary valuation methods

METHOD	ABBREVIATION	METHOD	ABB.
Effect / Change (loss or gain) / Variation on / in Production / Productivity / Income / Earnings		**Human Capital / Cost of illness approach**	**HC**
Effect On Production	EOP		
Financial compensation payable		**Travel Cost Method**	**TCM**
Linear or quadratic programming		Zonal Travel-Cost	
Econometric models		Individual Travel-Cost	
Production Function / Change in Productivity / productivity method / net factor income method / derived value method	PF	Random Utility Models	
Traditional type model			
Optimization models		**Mitigation/defensive costs (averting expenditure)**	
Econometric models		**Preventive/protective Costs/Expenditures**	
Household production function	HPF	**Substitute Costs**	
		Replacement costs	
Contingent Valuation Method	**CVM**	**Restoration Costs**	
Mail survey		**Relocation Costs**	
Face-to-face interview			
Phone survey		**Pricing**	

Bidding games		Public Pricing	
Open-ended question		Market Pricing	
Closed-question / dichotomous / referendum		Capital asset pricing	
Payment card			
Experimental analysis		**Revenue**	
Discrete choice		Tourism Revenue	
Hedonic CV			
Contingent Ranking / classification	**CR**	**Benefit Transfer**	**BT**
Contingent ranking with economic valuation			
		Group Valuation method	
Choice Experiment	**CE**		
Hedonic Methods			
Hedonic Prices Method	HPM		
Repeat Sale Model			
Hedonic Wages			

Figure 23: Main valuation methods and their basic rationale

METHOD	THEORIC PRINCIPLE	METHOD	THEORIC PRINCIPLE
Effect On Production (EOP)	Measure the value of an environmental improvement resulting from the implementation of an environmental regulation by the value of the change in output production (costs) it causes (Garrod and Willis, 1999).	**Substitute Cost**	Estimates the monetary value of a non-marketed good that can either be a consumer good or an input factor, and which has a marketed substitute, by the saved cost of using the marketed substitute (Markandya et al., 2001)
Production Function (PF)	Measure the value of an environmental good/service by its contribution (positive or negative) to the economic activity (production of marketed goods) and to the individuals' utility (Garrod and Willis, 1999). A change in supply of environmental goods can impact the delivery of marketed good for instance.	**Replacement costs**	There is an externality impacting an environmental asset/resource/amenity and this method values it by the actual cost of replacing it (Ledoux and Turner, 2002) after it has been damaged (Garrod and Willis, 1999)
Household Production Function (HPF)	Measure the value of an environmental good/service by its contribution (positive or negative) to the household' utility (Garrod and Willis, 1999).	**Restoration Costs**	It assesses the value of a natural resource by how much it costs to restore it to its original state (Ledoux and Turner, 2002) after it has been damaged (Garrod and Willis, 1999)

Contingent Valuation Method (CVM)	Value some environmental good by eliciting (via asking) either individuals' WTP for an expected improvement in the quantity or quality of this good, or individuals' WTA a compensation for a deterioration in the provision of this good (Markandya et al., 2001).	**Relocation Costs**	An externality impacts the environment and the benefits of avoiding environmental damage are estimated by using the actual costs of site relocation due to a degradation in the ambient environment (Markandya et al., 2001)
Contingent Ranking with economic valuations (CR)	Respondents are asked to rank two or more of the alternatives options suggested, in order of preference (Markandya et al., 2001)	**Public Pricing**	Use of public investment (land purchase, monetary incentives) as a surrogate for market transactions (Garrod and Willis, 1999)
Choice Experiment (CE)	Hedonic method that values the attributes that comprise a specific environmental good (type of attribute-based method)	**Market Pricing**	Use of market prices
Hedonic Prices Method (HPM)	The environmental quality is seen as an attribute of the land/property, and its value is deduced from analyzing the variability of real-estate and land prices (Rousseau de Vetter, in Zuindeau, 2000) to which the environment is related (Markandya et al., 2001).	**Capital asset pricing**	The value of a resource stock can be expressed as the Net Present Value (NPV) of the stream of service flows it is expected to yield over the lifetime of the resource (Markandya et al., 2001)
Travel Cost Method (TCM)	Values monetarily the recreational benefits procured to individuals by their visit of a non-priced recreation site (Garrod and Willis, 1999) by using the costs of travelling to this site born by households.	**Tourism revenue**	Values a natural site by the revenue that tourism to this site brings.

Human Capital Approach (HC)	Values an environmental attribute through the effect it has on human health (Garrod and Willis, 1999) and on the economic activity/productivity. In the Cost of Illness approach, the financial costs of illness caused by for example air pollution can be calculated by adding the costs of treating an illness to the costs of lost work-time (Markandya et al., 2001).	**Benefit transfer method**	Transposition of monetary environmental values estimated in one case and one site (…) to another site (Garrod and Willis, 1999)
Mitigation/defensive costs	There is an externality impacting a non-marketed environmental commodity (clean air), and this method assesses the value of this commodity through the amounts individuals and private groups are WTP (expenses) for marketed goods and services to mitigate the externality (Garrod and Willis, 1999) or the damages caused by it (Markandya et al., 2001)	**Deliberative Valuation**	Group discussion lead to deliberation about the monetary valuation of the environmental good
Preventive expenditures	There will be an externality impacting a non-marketed environmental amenity if people do not spend money to prevent it, and this method assesses the value of the commodity through the amounts individuals are WTP for market goods and services to prevent the externality (Garrod and Willis, 1999)		

Basically, there are market and non-market valuation methods, Champ et al. (2003) defining market valuation methods as the methods used when the economic channel though which human well-being is affected is market. Market valuations, like prices, do not focus directly on the satisfaction of individuals but rather use existing information about the monetary value

of biodiversity. The effect on production method for instance, which measures the value of an environmental improvement resulting from the implementation of a environmental regulation by the value of the change in output production (costs) it causes (Garrod and Willis, 1999), is a market valuation method, while travel cost method, which values monetarily the recreational benefits procured to individuals by their visit of a non-priced recreation site (Garrod and Willis, 1999) by using the costs of travelling to this site born by households, is a non-market valuation.

Figure 24: Non market valuations methods

Contingent Valuation Method (CVM)
Attribute-based Methods
Multiple good valuation Method
Travel Cost Method (TCM)
Hedonic Price Method (HPM)
Defensive Behavior Method (DBM)
Damage Cost Method (DCM)
Benefit Transfer Method (BTM)

Source: Champ et al. (2003)

One can also distinguish between cost-based and price-based methods (TEEB, 2010), or between cost-based and other valuation methods (Chevassus-au-Louis, 2009; SCBD, 2010; TEEB, 2010; Dosi, 2000). Cost-based methods are those using proxies about markets values ("market signals", Champ et al., 2003) that are directly about the environmental good or service but that are not market prices (also called objective valuation methods by Markandya et al, 2001). The Replacement Cost Method, which value a change in an environmental asset/resource/amenity by the cost of replacing it (Ledoux and Turner, 2002) after it has been damaged (Garrod and Willis, 1999), ranks for instance among cost-based methods. Again, the focus is not directly on individual preferences but rather in existing monetary values. However, some methods use costs and do focus on individuals' preferences, and are not ranked among cost-based methods. As Markandya et al. (2002) suggest it, valuation methods relying on costs that are not directly resulting from an environmental change are usually not ranked among cost-based methods, and so the Travel-Cost method (TCM) is not ranked among cost-based methods (Garrod and Willis (1999), Dosi (2000), Markandya et al. (2001), Markandya et al. (2002), Chevassus-au-Louis (2009), TEEB (2010)), and does analyze individual's preferences whereas the Replacement Costs method is.

Figure 25: Some cost-based methods

Effect On/ Change in Production/Productivity (EOP)
Opportunity Costs Measures (OC)
Human Capital (HC), Cost of Illness (COI), Loss of earnings and Dose-Response functions (DR)
Replacement, Restoration, Relocation Cost (RC)
Preventative Expenditures (PE)
Mitigatory Expenditures / Mitigation Costs
Averting Behavior (AB)
Avoided Cost

Source: adapted from Garrod and Willis (1999), Markandya et al. (2001, 2002), Chevassus-au-Louis (2009)

We see therefore that a major difference exist between methods that are considered as direct (Pearce and Turner, 1990) because they are directly based on individual preferences, and methods that are considered as indirect because they are based on market signals, and/or on physical data and Dose-Response functions (DR). Those two kinds of methods belong to fundamentally different categories, which Schröder et al. (2009) suggest calling the behavioral linkage (based on preferences) methods from physical linkages methods.

Finally, among the valuations that do estimate individuals' preferences, we find the stated-preferences methods and the revealed-preferences methods. The stated preferences method attempt to elicit preferences of individuals by asking them directly those preferences (by stating a monetary value or a preference ordering), within the context of a fictive or hypothetical market (stated preferences methods) as those preferences are not translated in acts. Among those methods, we find methods that value either goods or the attributes of those goods (Champ et al., 2003), either by gathering stated WTP or by using stated choice, ranking and ratings (Champ et al., 2003). As for revealed preference methods, they attempt to elicit individuals' preferences though the observation of actual, observed, market-related behaviors of individuals about some goods and services related to biodiversity but not directly about biodiversity (revealed preferences methods) (Markandya et al., 2001; Champ et al., 2003). Those behaviors are assumed to reflect utility maximization subject to constraints, and so revealed preferences methods involve a kind of detective work in which clues about the values individuals place on environmental services are pieced together from the evidence that people leave behind as they respond to prices and other economic signals (Champ et al., 2003).

4.4. What is valued by traditional monetary valuations of biodiversity?

In section 1, we have introduced biodiversity as the diversity of the living which can be seen as a property and though its functional dimension. We have assumed that economics is concerned with the consequences of biodiversity losses on the provisions involved in human provisioning systems and with the consequences of biodiversity losses on the natural processes and conditions that insure the supply of those provisions. In section 2, we have introduced the theory of economic value, which understands the economic value of a good for an individual as the total satisfaction that this good provides to the individual who is consuming/enjoying it. In section 3, we reviewed the different traditional valuation methods and their basic approach to valuation in order to grasp the kind of monetary value and information they measure. In this section, we confront the status that biodiversity has in valuation methods (sections 2 and 3) to the economic status of biodiversity (as defined in section 1), in order to identify some (this section has not the ambition to be exhaustive) of the aspects of biodiversity that are taken or not, into account, in economic studies and valued by monetary valuations. We particularly pay attention to the functional dimension of biodiversity.

First, what are the implications of the marginal foundations of the theory of economic value? Operationally, the marginal approach is usually fine because it is often small changes in availability that are at issue when individuals or policy makers are making decisions (Heal, 2000). But unfortunately, some of the human impacts on ecosystems are far from small (Heal, 2000) and the consequences of biodiversity losses are not necessarily progressive and linear. Resilience is not altered by marginal changes in an ecosystem function, but often by combined changes in a range of ecosystem elements and functions, and so the valuation exercises of single ecosystem functions are rather misleading because their search for marginal values may have no real meaning (Kosoy and Corbera, 2010). Even the extinction of one species (which could be considered as a marginal change) can result in non-marginal changes, like cascading changes[84], and to the disadvantage of humans (Heal, 2004). So “we cannot easily tell a priori what species are essential and what are not, so there is often a risk

[84] The literature on trophic cascades is well developed. Cascades are defined as reciprocal predator–prey effects that alter the abundance, biomass or productivity of a population community or trophic level across more than one link in a food web (Pace et al., 1999). Those cascades have ultimately impacts on the provisions available for humans.

that an apparently small change in a set of species will have effects far beyond those initially anticipated" (Heal, 2004). Thus, valuation methods may not be acceptable as measures of the values of biodiversity in proximity of 'Critical Threshold'[85] (Farber et al., 2002) and when economic and ecological systems are dramatically altered (Farber et al., 2002). In addition, because it may be difficult to determine when we are confronted to 'non-marginal' situations because the knowledge about biodiversity losses is limited and uncertain, and so applying marginal valuations to biodiversity bares the risk of neglecting bigger changes in biodiversity as a property and biodiversity functional dimension. So it seems difficult to estimate the economic value of changes in biodiversity, because of the uncertainty of their marginality, and it is probably impossible (or non-sense) to value the whole economic value of biodiversity, as it would be infinite.

Then, another fundamental basis of the economic theory of value is utility (utility-based or welfare-based approach). Biodiversity is a worldwide characteristic of nature, which can be valued quite differently by individuals depending on their conditions of living, their cultures, and their own uses and relations to biodiversity. For instance, the consequences of biodiversity losses on the provisions involved in human provisioning systems can be more or less dramatic, depending on the technologies available in the economy considered (technology can improve the chance of substitution/replacement/alternatives to some provisions), depending on the richness of individuals and the globalization of their economy (and therefore their access to global alternative provisions), i.e. depending on the dependence of the economies to their provisions, including basic provisions such as food. This means that utility cannot really play the abstract measure that it is assumed to play, and so the utility-based valuation approach to biodiversity implies enormous ethical and technical difficulties, to do interpersonal comparisons and aggregations of value of biodiversity. Those comparisons may however be necessary, as Gowdy (2004) suggests it, for making any welfare judgment.

In addition, the reliance of monetary valuations on individuals' preferences may provide monetary valuations that are far from taking into account all the values of biodiversity, including the functional role and value of biodiversity, because there is strong evidence of a high degree of ignorance concerning individuals' understanding of the very concept of

[85] The risk to neglect thresholds is reinforced by the neoclassical assumption of substitutability of goods (Common, 2007; TEEB, 2010).

biodiversity (Nunes and Van den Bergh, 2001). We already saw that the scientific knowledge on the complex object biodiversity is limited and uncertain.

Fundamentally, normativity and value judgments (such as interpersonal comparisons) are rejected and to be avoided in the utility-based theory. It attempts to be objective while being based on subjective preferences, which raises the problem of being partially blind the complexity of the object (preferences, individuals' valuations) being used for building monetary valuations. Indeed, it is often assumed that the way preferences are formed is not an economic question (Godard, 2004). Sen (1999) identifies two ways in which the utility-based theory neglects the complexity of individual's preferences. It neglects the physical and mental conditions of living of the valuator (he could be handicapped, poor, living a polluted area) which he calls the 'physical condition neglect', and it neglects to understand the factors influencing a person's own valuation exercise (some individuals are more easily pleased than other) which he calls the 'valuation neglect'.

Those neglects of the neoclassical theory have consequences on the overall neoclassical approach to the economic value. It becomes conceptually confused, with notions such as individual utility, welfare and well-being being often used interchangeably[86] (when there is no public good or externalities in the utility function) even though those notions were not initially confused[87]. "*Formal economics has not been very interested in the plurality of focus in judging a person's states and interests. (…) There is powerful tradition in economics analysis that tries to eschew the distinctions and make do with one simple measure of a person's interest and its fulfillment. That measure is often called 'utility'* (…). *While utilitarian economists have seen utility as satisfaction, happiness, or desire-fulfillment, modern economists' recourse to a loose usage of utility, it also for other purposes, standing for whatever the person maximizes and simply for the person's well-being or advantage. (…) Mathematical exactness of formulation has proceeded hand in hand with remarkable inexactness of content"* (Sen, 1998).

So the assumptions of the neoclassical theory on the nature of individuals' preferences that do exist are therefore basic and restrictive, and can be seen as stringent requirements (Gowdy,

[86] For one example, chosen arbitrarily, see Fredrick et al. (2002) writting well-being in period t+k, $U(C_{t+k})$.
[87] Samuelson claimed that any connection between utility and any welfare concept were disavowed in his work on the Discounted Utility Model (Fredrick et al., 2002).

2004) that do not allow real behaviors to be taken into account. Indeed, they have problems with false beliefs, changes in preferences, persons holding multiple conflicting preferences, and non-social preferences such as racism (Hausman and PcPherson, 1996 in Brekke, 1997). They also have difficulties to admit other motives that maximization of individual well-being for choice behavior (Brekke, 1997).

What is measured by utility then? Needs (before being satisfied), satisfaction, happiness (the result of being satisfied)? The tendency is to see utility as a source of value rather than an evidence of value (Sen, 1999), which encourages neglecting the individual valuation process. This is why Sen (1999) recommends to look at the functioning of individuals, i.e. at what the person succeed in doing with the commodities and characteristics at her/his command rather than at the ultimate utility he derives from it (the functioning is posterior to having the good, and prior to having utility). Some fundamental limits of valuations are regularly raised and can be explained by Sen (1999) analysis. We already mentioned the fact that individuals' valuations depend on individuals' conditions (income and property rights), on their level of information, but we can also mention the fact that valuations consider individuals' preferences already formed and that valuations will be able to reveal them. However, valuations may risk to construct them during the process of valuation estimation or to misinterpret the relation existing between choices and the preferences motivating those choices. Sen (1999) underlines how it is not the choice but the motivations that underlie choice that reveal preferences, a comment that drastically undermines the revealed preference valuation methods, and more generally, the way theory understand preferences and acts and indicators of individuals' utility.

The few limits of the economic theory of value that we just analyzed are extremely relevant for the valuation of biodiversity. Schematically, it cannot value biodiversity outside of the safe human use zone and in the case of non-marginal changes, and it can only partially value biodiversity's contribution to the capacities and opportunities of humans to live well by focusing on utility and individuals' preferences. We can illustrate those points by discussing more precisely the approaches of some of the valuation methods to biodiversity.

A gap exists between the economic status of biodiversity that we discussed in the first, and the economic status it is implicitly given in monetary valuations, i.e. the status of an

environmental asset. More precisely, if we refer to the figure 22 we see that valuations methods value environmental change, natural resource, environmental good and service, environmental asset, resource, amenity, attribute of an environmental good, resource stock or natural site. However, we saw that biodiversity is neither a good, nor a resource or an asset. We suggested that it is a systemic entity that can be seen as a property and a process, with its functional dimension.

We saw that the TEV is decomposed into use values, passive values, the option value and the existence value. Already the category use-value is difficult to apply to biodiversity, because it is hard to distinguish in our uses of nature, the part that is attributable to biodiversity. We can enjoy a natural site and value our recreational time there with the TCM (revealed preference method), but this approach has enough limits and relies on enough assumptions (see the following table) to make the valuation of the biological diversity of this site (biodiversity as a property), feasible. With this method, a change in the value of biodiversity is only taken into account when it results in the modification of people's behavior (Boisvert and Vivien, 1998). However, it may be really difficult to observe such difference in behavior and to attribute with some confidence those change in behavior to change in biodiversity (except for drastic changes in biodiversity that may not be considered as marginal). And even if we could, changes in behavior may reveal the real preferences and motivations of the individuals regarding biodiversity.

Figure 26: Limits and assumptions of the Travel Cost Method (TCM)

	...the individuals	...the object being valued	...the data and the technics	
Travel Cost method (TCM)	Individuals considered are only those actually visiting the site studied. Those not visiting the site are not considered, neither is their value for the site (Scherrer, 2004)	The quality of the site is supposed to be maintained when visit frequency increases (Bishop and Heberlein, 1979)	Travel costs are supposed to be homogeneous (Scherrer, 2004), even though individuals have not the same capacity to access the site (Bishop and Heberlein, 1979).	Complexity of the treatment of substitutes sites (their existence and their characteristics) (Garrod and Willis, 1999)

	The TC to a site is assumed to be a measure of recreational preference, however this assumption is violated when individuals move to an area to gain improved access to particular sites (Gibson, 1998 in Garrod and Willis, 1999)	Cannot be used for sites that do not require travel (Bishop and Heberlein, 1979)	As all the techniques using data derived from on-site questionnaire surveys, TC is vulnerable to sample selection effects (Garrod and Willis, 1999)	Visit frequencies are homogeneous (Scherrer, 2004)
	Whatever assumption is selected for the treatment of the value of time, it would not accurately represent reality (Garrod and Willis, 1999). It is a difficult, debatable (Bishop and Heberlein, 1979) and still unresolved (Scherrer, 2004) problem.	A change in the value of biodiversity is only taken into account when it results in the modification of people's behaviour (Boisvert and Vivien, 1998)	Bias resulting from the fact that price actually paid are used instead of the prices that people would be willing to pay for the good. This results in an under-valuation of the good (Scherrer, 2004)	Complex when studying multiple-goals trips (Bishop et Heberlein, 1979); multi-activity, joint-activity, multi-destination and joint purpose trips raise reparability problems (Garrod and Willis, 1999)
	The opportunity cost approach of time, often used, relies on the strong assumption of labor equilibrium (Garrod and Willis, 1999).	Only the changes that already happened are considered (Boisvert and Vivien, 1998)	Difficulty in identifying the determinants of people choices and the way to measure their influence (Boisvert and Vivien, 1998)	There are huge differences in results depending on the costs we consider (oil, car depreciation, …) (Garrod and Willis, 1999)
	People's preferences are similar (Scherrer, 2004)		Difficulty to be exhaustive in the identification of costs factors (Scherrer, 2004)	The cost of data acquisition is high, trade-offs must be done in case of a limited budget and imprecision and measurement errors can result (Scherrer, 2004)

Another method that often used to value “biodiversity” is the Contingent Valuation (Garrod and Willis, 1999; Bateman et al., 2002). This is because it is assumed to be the only method

that estimates, not only non-occurred and potential changes (Boisvert and Vivien, 1998; Arrow et al., 1993) and passive use-values (Arrow et al., 1993, Nunes and Van Den Bergh, 2001), but also non-use values (Scherrer, 2004; Meyerhoff and Dehnhardt, 2007; Ledoux and Turner, 2002; Nunes and Van Den Bergh, 2001). While the contingent valuation offers the possibility of a stated preferences (unlike the revealed preferences that require to observe behaviors related to biodiversity), to question individuals about biodiversity per se (and their preferences), it is rarely used this way. It may focus on the valuation of particular species for instance, thereby valuing the "existence" of the species itself and not its value as a member of a varied biological or as a part of a functioning system.

Then, despite the information sessions that respondents undertake, respondents may lack understanding about biodiversity (Bullock et al., 2008; Allen and Loomis, 2006; Ludwig, 2000) and about the CV's scenarios, an information problem that we already mentioned. This lack of understanding can reflect the reality, but it can also prevent the CVM from revealing the actual preferences of people as they may have different preferences once they understand better the object of study. In addition, people may feel encouraged to make up numbers in order to answer the survey, and to base their statement on impulsive preferences, resulting in overvaluations of symbolic species and under-valuations of ugly however ecologically important species. This would reflect a real fact, i.e. that human are prone to prefer whales to worms or sharks, but as any utility/preference based methods, it would not reflect the economic value that worms have for agriculture productivity and human food supply and security for instance, which are facts that have the potential to drastically alter some impulsive answers. This illustrates the difficulty for utility/preference based methods in particular, to take into account the functional value of biodiversity.

Arrow et al. (1993) recognize the difficulty to provide adequate information to respondents, and to be sure that individuals have absorbed the information. The complexity of the notion necessarily limits the amount of information that can be communicated (Allen and Loomis, 2006). Moreover, Brookshire et al. (1982) remind us that CVM produce useful results when respondents have market experience for a particular good, which is not the case for biodiversity because it is not even a good. "*Most members of the public have never considered the value they hold for the continued existence of some poorly understood species residing in a far off land. (…) Appending values to biodiversity, or making choices which*

involve both monetary estimated and species, is likely to be widely outside the normal range of decision making for a person – and therefore unlikely to yield robust or meaningful values" (Balmford et al., 2011). Then, the risk that methods form rather than reveal preferences is exceptionally high with contingent valuations. The whole CV study and its questionnaires may have had an extremely high influence on individuals' preferences. A review of some CVM's limits and assumptions follow, which could further illustrate its difficulties in dealing with biodiversity per se.

Figure 27: Limits and assumptions of the Contingent Valuation Method (CVM)

	...the individuals	**...the individuals**	**...the data and the technics**
Contingent Valuation Method (CVM)	Risk of overestimation of the real WTP (Arrow et al., 1993) because stated WTP concerns a situation and in reality there can be several programs. Hypothetical WTP do not considerations of the budget constraint (Arrow et al., 1993)	Comparatively to the time spent to thinking about- and buying- a good, the interview duration is too short (Scherrer, 2004)	Often, WTR are too biased so use of WTP, even for the lost-values (Arrow et al., 1993)
	We ask people to give a price to non-market goods, while they have no or very limited knowledge about them (Ludwig, 2000; Bullock et al., 2008) and no market experience with them[88].	Strategic bias (Bishop et Heberlein, 1979; Scherrer, 2004) as people might weight up the impact of their answer on what will actually happen (Bishop and Heberlein, 1979)	There can be bias affecting the selection of people interviewed (its interests, its representativeness, his knowing of the site (Scherrer, 2004))
	As social psychology teaches us, what we would do and what we do differ (Bishop and Heberlein, 1979), there is a Hypothetical bias (Scherrer, 2004), respondents to not actually have to pay their WTP (Meyerhoff and Dehnardt, 2007).		Suffer from the bias all surveys in general (4) and questionnaires (Scherrer, 2004) face; like the influence of the wording, the question order…(Scherrer, 2004)

[88] Brookshire et al. (1982) recognizes that « informed populace with market experience for a particular public good allowed the successful application of the survey approach ».

	Embedding effect (Scherrer, 2004; Arrow et al., 1993), i.e. the fact that individuals can have the same WTP for small or big changes		Difficulties to define the zone of population to interview (Arrow et al., 1993)

We can either consider that those limits of valuations can be overcome by improving the theory and the method (reformist approach) or that they are big enough to require more drastic improvements (transformational approach) in the theory and its assumptions. This article assumes that the second approach may be required for attempting to really value biodiversity, or even some aspects of biodiversity, but also that the first approach is also required to identify and improve the kind of information that the existing valuations provide. They don't deny their usefulness, but we insist on the need to identify their content and their conditions of uses. We pursue our analysis and bring additional arguments supporting those comments.

A gap exists between the economic notion of biodiversity value and natural sciences and ecology's notions of value. In natural sciences and ecology, value can refer to (1) the degree to which an item contributes to an objective or condition in a system, to (2) the fitness of species in natural selection models which maximize the fitness of species, to (3) the importance of the contribution of natural ecosystems and their components to something (human survival for instance) or to (4) energy (in some biophysical theory of value) (Farber et al., 2002). With such definitions[89], it is likely that specific ecosystem structures and processes that have some functional role in an ecosystem and have therefore some 'value' for natural scientists and ecology experts (Farber et al., 2002), had no monetary or even economic value, even though they contribute ultimately to human provisioning systems and human well-being. Indeed, in the economic theory, those components are valued by the utility they provide, through use and non-use, to individuals and so the concept of functional value is totally absent from this representation (Vatn and Bromley, 1994), even though the value of those components should reflect somehow their contribution to the whole functionalized system (Vatn and Bromley, 1994).

[89] Even with definition (2) which bears close similarities to economic utility maximization models (Low, 2000 in Farber et al., 2002).

Basically, by looking at the utility provided by biodiversity, economics tends to focus on direct 'end-uses' such as consumption and production, rather than on indirect values such as the 'contributory value' and 'primary value' or even and 'infrastructure value' of biodiversity (Nunes and Van den Bergh, 2001). Even in the Ecosystem Services approach, a quickly developing interdisciplinary approach (economics, natural sciences, politics (Barnaud et al., 2011)), which studies the whole set of benefits that humans do or could derive from a well-functioning nature thanks to biodiversity, natural scientists try to elucidate the potential contribution of biodiversity in natural functions and the links between natural functions and the provision of ES (see Annex)[90], but economics focuses on the enumerated variety of goods (food, water, raw materials, energy) and services (supporting, provisioning, regulating and cultural services (TEEB, 2010b) that human societies derive from a diverse nature, and value them. The identified biophysical structure and processes, and functions necessary to the provisions of ES are not valued[91], and so the impacts of biodiversity losses on the conditions of provisions of the provisioning systems are absent mostly from the valuation approach[92].

Therefore, many authors emphasized the fact that the TEV cannot represent the whole economic value of biodiversity (Pearce and Moran, 1994; Braüer, 2003). "It is tempting to think that economists have captures all there is to know about economic value in the concept of TEV. But this is not correct" (Pearce and Moran, 1994), at least[93] because the value of the underlying function of ecological systems and biodiversity, which are prior to ES and upon which all ES are contingent in some sense, is not taken into account. For Pearce and Moran (1994), it corresponds to a 'glue' that holds everything together, and this refers more or less to the functional dimension of biodiversity that we already mentioned. If this 'glue' has economic value, then then there is a total value to an ecosystem or ecological process which

[90] A clear difficulty exists in identifying causal chains. The relationships between biodiversity and the provision of ES are still debated and hard to make (TEEB, 2010). Ecosystem properties and ecosystem goods and services depend on biodiversity (Hooper et al., 2005 in Ronnback et al., 2007), but deeper ecological understanding of this complex relationship is still limited (Kremen et al., 2005 in Ronnback et al., 2007). This is why one major concern within the ES literature (and in ecology more generally) today is the identification of the causal - chain biodiversity - ES.

[91] We do not discuss here the fact that some services are actually called functions by some authors (TEEB, 2010) speaks about supporting services, and regulation services when De Groot (1992) speaks about regulation functions). The distinction may often be difficult to make between functions and services, especially because the term 'ecosystem function' itself has been subject to various, and sometimes contradictory, interpretations. It is defined by De Groot (1992) as 'the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly' (De Groot, 1992).

[92] Norgaard (2010) warns us about the risk that the ES brings to focus on the ecological capital providing ES and not on the direct drivers of change to the ecosystems.

[93] Another argument often found in the literature justifying the assertion that the TEV is not total, is that economic values does not capture (nor are designed to capture) the intrinsic value. (Pearce and Moran, 1994).

exceeds the sum of the values of the individual functions (Pearce and Moran, 1994) and so the value of biodiversity cannot be not equivalent to the sum of its components (Maris and Réveret, 2009).

A theory may be required to estimate such a value, as it is often assumed that primary value are not measurable in economic terms (Braüer, 2003) and that ecological functions are difficult to grasp (Boisvert and Vivien, 1998) and observe (Pearce and Moran, 1994) and so to value before it is too late because they are lost or disappear (De Groot, 2002; Pearce and Moran, 1994). Vatn and Bromley (1994) assumes for instance that in a fully functionalized system, each part must actually be as valuable as the whole, and that the value of any single component cannot be understood separately from its contribution to the whole (Vatn and Bromley, 1994), as they present a uniqueness in the relation to the whole system of which they are a part (Vatn and Bromley, 1994). Among many other dimensions of the theory that we would deal with here stands the hypothesis of substitutability between "goods and services". However, substitutability is quite more debatable regarding functions, and is quite debated even in natural sciences (rivet hypothesis versus redundant species hypothesis). A bear may substitute for an elk in consumption, hunting, and in a wildlife viewing experience even though bears and elk are not substitutes in terms of ecosystem function (Farber et al., 2002)

4.5. The relevance of traditional monetary valuations of biodiversity

Before all, we need to introduce the idea of relevance. For Hezri and Dovers (2006), an information is relevant when it "strikes a chord with its intended audience", and this audience is here public decision makers. To determine the relevance of some information piece, one needs to know the level of "resonance" of the information with the audience, and two criteria have to be considered for that: the content of the information and its legitimacy. Those two notions are obviously intertwined. Indeed, legitimacy depends among other things on the content of valuations, i.e. on theoretical and empirical principles that have been used to realize valuations. But it also depends on others things, as the same particular valuation method and content can enjoy different legitimacy depending on the country for instance, as it is the case for the contingent valuation more welcomed in the USA than in Europe. The

process itself, of valuing biodiversity monetarily can be considered as legitimate or not and influence the legitimacy of valuations to the eye of public decision makers. This means that both the action of valuing biodiversity and the results/content of this valuation process play a role in the legitimacy of valuations. In addition, valuations derive also some legitimacy from the roles they are expected to play and from the uses that are made of them. Thus, the relevance of valuations depends on the content and the legitimacy of those valuations, and the legitimacy of valuations depends at least, on the action/process itself of valuing monetarily biodiversity (it may be argued that it is ethically wrong to value monetarily biodiversity), on the principles used to do so and therefore on the content of the valuations (the assumptions of the valuation methods used, for instance the recourse to individuals' preferences, can be rejected), and on the uses that are made of those valuations (the use of valuations in CBA can be rejected while the estimations of some benefits or costs can be welcomed). In this article, we are mainly focusing on the content and the legitimacy of the content of valuations.

Scientists are responsible for the scientific robustness of valuations and so for the elaboration of valuations' content. However, in the particular case of the neoclassical theory, we saw that the theory itself has many drawbacks and does not only rely on technical principles, it also rely on strong theoretical and ethical assumptions. This undermines potentially the scientific legitimacy of the theory, and so to improve it, it is necessary that valuations' content be clear, transparent, and easily graspable for public decision makers. However, we also need to realize the fact that the legitimacy of valuations to the eyes of public decision makers does not result only from an objective judgment. Public decision makers act with limited rationality (Simon, 1997), and face work constraints like political agenda, time pressure, and career management, that influence the kind of information they use and consider. Therefore, to make valuations relevant for public decision makers, a collaborative learning process (Innes and Booher, 2000 in Hezri and Dovers, 2006) is required between scientists and public decision makers. The analysis we further provide of valuations' content and legitimacy is therefore just a starting point for such process.

First, valuations cannot be relevant if their content is regarded as exhaustive while it is partial. They do not measure the TEV of biodiversity or the importance of natural environments to society, "only biology can do that" (Heal, 2000). Because they cannot estimate all the benefits and costs related to biodiversity losses, we cannot either expect that

CBA provide an efficient solution to public resource allocation issues. In addition, the focus of CBA on efficiency and its apparent objectivity is another dimension that raises concerns about its legitimacy in guiding/directing public decisions, on which a vast literature exists. But without the TEV and CBA, it is still meaningful and relevant to study how changes in the quantity or quality of various types of natural capital and ecosystem services impact some aspects of human welfare (Costanza et al., 1997) and human provisioning systems, which valuations can do. Farber (1987) for instance, provide an example of a cost-based marginal valuation of coastal wetlands via the valuation of the protection of property against hurricane wind damage that those wetlands provide. The marginal benefits of the wetlands are valued by estimating the increase in damage affecting one house when some marginal quantity of wetlands disappears.

Then, valuations do not value biodiversity per se but rather natural resource, environmental asset or environmental good and services existing partially thanks to biodiversity. Therefore, the usual comment that valuations provide at best lower bounds of biodiversity's value (Nunes and Van den Bergh, 2001) is superfluous. Valuations do not provide estimate of biodiversity's economic value, whether they attempt to value biodiversity based on the economic theory of marginal change in utility/preferences, or based on and other methods (market valuation methods, some cost-based and physical linkage valuations methods) providing some monetary value about biodiversity via the recourse to prices or costs. But there is perhaps no need to estimate the economic value of biodiversity per se to increase its protection. The tendency to value not only the physical products of nature that we can consume, but also all the other economic benefits associated with biodiversity and ecosystems (Emerton, 2005) may be a more effective and scientifically legitimate way to produce and use some valuations "about biodiversity".

Indeed, after the failure in reaching 2010 Biodiversity Targets by all members states to the Convention on Biological Diversity (SCBD, 2010; Djoghlaf, 2010[94]), the SCBD identified two explanations of those failures: the actions aimed at protecting biodiversity had not been directed enough to ensuring that human societies continued to receive the benefits from

[94] "We have failed, individually and collectively, to fulfil the Johannesburg promise made to them by the 110 Heads of State and Government to substantially reduce the loss of biodiversity by 2010." Statement by Ahmed Djoghlaf, executive secretary of the CBD at the opening session of the tenth meeting of the conference of the parties to the CBD, Nagoya, 18 October 2010.

ecosystem services over the long term, and they overlooked the underlying causes and reasons of biodiversity losses. Valuations of ES have therefore developed to estimate the benefits derived from "biodiversity", addressing the first of those two explanations. However, this may not have helped to deal with the second factor, i.e. the management of underlying structures and processes that facilitate ES generation (Ronnback et al., 2007). By evaluating end-benefits (Balmford et al., 2011), i.e. the monetary value of services when they are delivered (Wallace, 2007) in order to avoid the issue of double counting that can exist in the ES approach (Nunes and Van den Bergh, 2001) otherwise, valuations may have increased the already existing tendency of neglecting the underlying causes and reasons of biodiversity losses[95]. Preserving the flows of goods and services or preserving the functions and processes necessary for the provision of those flows is not equivalent, as the uses of goods and services can impact the functions and processes. We find here a fundamental tension already mentioned that can exists between ecological and economic concerns and values. And so in this context, valuations of ES are relevant but not alone. Public decision makers need to be aware of the complexity of the dynamic interactions between functions, values and processes (Boumans et al., 2002 in De Groot et al., 2002) and to care about the conditions necessary for sustaining the flow of goods and services from ecosystem, which valuations cannot provide.

Then, preferences based methods can be relevant for estimating the WTP of individuals for biodiversity. Weber (2003) for instance recognizes a potential use to the Contingent Valuation, despite all the limits this method has, in providing an interesting survey of the Willingness-to-Pay of citizens for biodiversity conservation – a relevant information for policy-makers regarding budget decisions and their acceptability. However, we introduced some of the numerous limits of this preference based approach (confused concept of utility, neglect of physical and mental conditions of living of the valuator, neglect of the factors influencing a person's own valuation exercise), and realized that those methods may not really reveal more than WTP. Multiple group valuation methods develop (participatory, deliberative) and may provide interesting alternatives to the traditional way of consulting individuals' preferences, allowing to avoid environmental CBA while aiding management decisions and policy design with the hope of broadening democracy (Spash, 2007). Not only in economics but also in other evaluative discipline such as accountability, authors call for

[95] And they have focused the attention on the realized benefits, even though the realization of many benefits may block the realization of others (Vatn and Bromley, 1994).

such participatory tools expected to improve democracy and reduce the domination of positivism and calculus by putting some limits to their recourse (Brown, 2009).[96]

Finally, biodiversity issues are so complex[97], uncertain (ecologically and socially)[98] and vast, that they require a diversity of complementary approaches to be dealt with, including a variety of economic methodologies (Beaumont et al., 2008; Gowdy, 1997; Brown, 2009) and a combination of quantitative and qualitative research methods (Ledoux and Turner, 2002). In this context, traditional valuations can gain in legitimacy by integrating such pluralistic framework of analysis and interdisciplinary approaches, and being transparent regarding their content and the information they can and cannot bring. Not only do we need to recognize the "uncertainty surrounding estimates of the environmental costs" (Arrow and Fisher, 1974) and to develop valuations under uncertainty, we need to confront uncertainty (Ludwig et al., 1993) and learn to manage it (Weber, 1995; Barnaud et al., 2011; Armworth et al., 2004), which can only be done by collaborating with other sciences. As Lapp (2005) suggests it, the complexity of anthropo-ecosystem makes mono-disciplinary academic partially inappropriate.

We just saw that traditional monetary valuations can estimate monetary values of some changes in environment having an impact on human provisioning systems, including some changes in the supply of natural goods and services, and monetary estimates of the WTP of individuals. Those valuations do not provide estimates of the economic value of biodiversity, nor do they provide valuations of the overall functional dimension of biodiversity. However, they can provide numerous relevant information about the tangible economic benefits of 'biodiversity' for public decision makers, once their limits are recognized, and that the legitimacy of their content is increased. Because they correspond only to one approach to biodiversity's value while there are other numerous disciplines and approaches possible to complex and uncertain biodiversity issues, an interdisciplinary and pluralistic approach to biodiversity is needed, in which valuations can be integrated. This will help filling the gaps of traditional monetary valuation's approach, but also improve them. Brito (2005) for instance underlines huge misunderstanding related to life science that

[96] See the literature on post-normal science for more information about the justification of public involvement into the expert valuation process.
[97] Biosphere is too complex to be well understood soon (Barret and Grisle, 1999).
[98] The long-run implications of permitting the biological reservoir to be reduced are shrouded in both "social" and "natural" uncertainty (Bishop, 1978).

Mendonca et al. (2003) have made in their valuation article. In return, valuations will provide fundamental information about benefits and costs that are necessary to manage funds allocated to biodiversity. We can illustrate quickly the relevance of monetary valuations in some concrete situations.

There are some cases in which the monetary net benefits of preserving biodiversity clearly outcome or at least equal the net benefits of not preserving it or of investing in other projects. In those cases, there is no need of knowing biodiversity's TEV or to realize an environmental CBA to establish valuations of the tangible benefits of biodiversity. Emerton (2005) mentions several examples of ecosystem services that have phenomenally high economic value, such as the waste water treatment services that particular freshwater ecosystem provides and that justified, in the African city Nakivubo, zoning the ecosystem and protecting it as a part of the city infrastructure rather than reclaiming it for future housing and development.

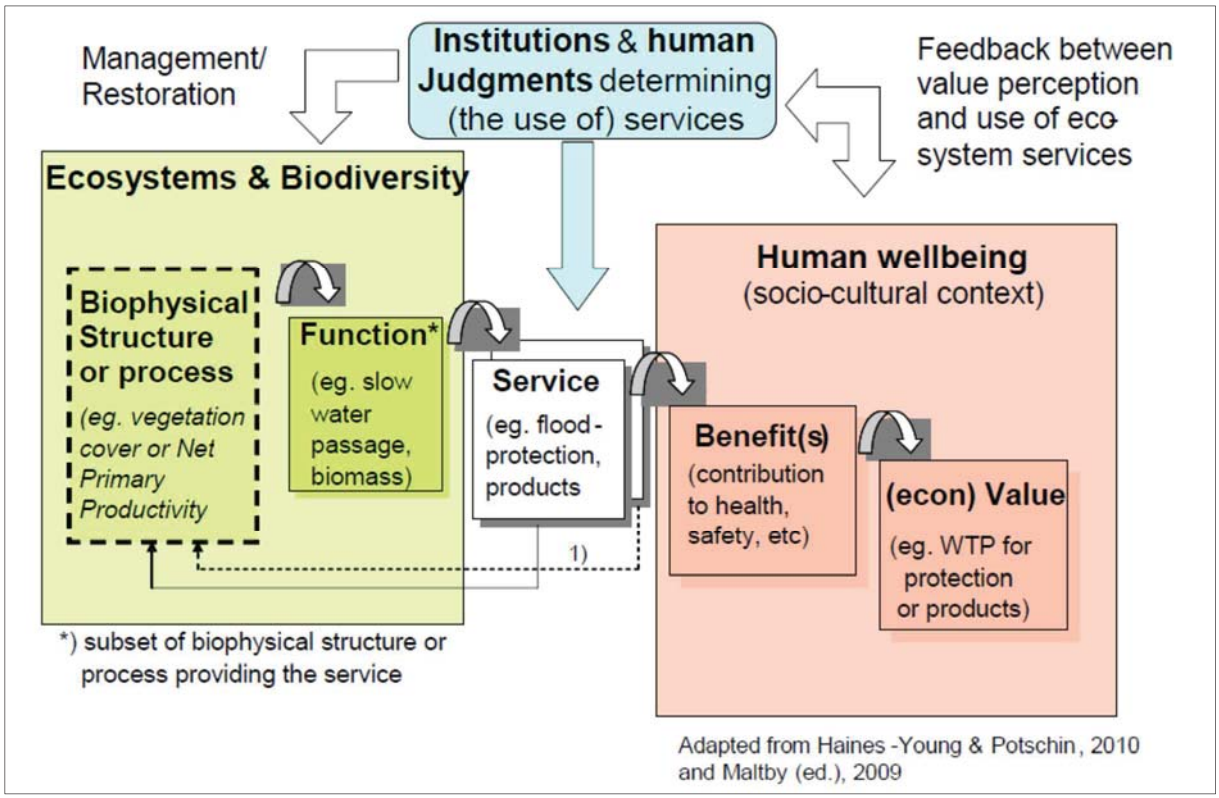
However, economic returns on investments preserving biodiversity are not always obviously high and comparatively desirable to other projects. There can be a real conflict between economic and ecological concerns (Brito, 2005). Biodiversity preservation yields benefits that we saw are difficult or impossible to estimate monetarily with traditional valuation methods. This leads some authors to think that improvements in the valuations ex-ante of those benefits (and research on discounting, non-use valuations…) could ultimately make investment in biodiversity more desirable. However, because of the drawbacks we mentioned of traditional valuation methods, we suggest that alternative approaches and methods, rather than traditional valuation methods, could complete our knowledge on the desirability of preserving biodiversity. In addition, ex-post valuations studies of biodiversity losses resulting from already realized projects can support those alternative approaches by estimating the foregone benefits of lost biodiversity that would have been ex-ante hard or impossible to value. Emerton (2005) provide an example of ex-post valuations that could serve this purpose, with a case in which the economic return on investment of building a dam seemed higher than preserving the natural site, but was actually lower once the lost benefits of flooding that used to happen before the dam were taken into account.

4.6. Conclusion

Pearce (2007) identifies three dimensions of the relevance of monetary valuations of biodiversity. They provide an estimate of biodiversity's value that allows us to realize that we don't invest enough in biodiversity's preservation; they provide monetary estimates of budgets, benefits and costs that allow us to realize that comparatively to other public spending we don't allocate enough resources to biodiversity; and they provide estimates of individuals' WTP which allow us to realize the gap existing between the amounts we pretend wanting to spend for biodiversity and the reality. In this article, we assume that valuations can indeed contribute to those three dimensions, but not by pretending valuing biodiversity's value, and rather by providing monetary estimates of tangible benefits and costs of related objects to biodiversity. Only in combination with other sciences, especially natural sciences, can valuations help grasping the value of biodiversity to human societies.

ANNEX

Figure 28: TEEB (2010)'s representation of causal-chain between biodiversity and ES



Source: TEEB (2010)

(Original title: "the pathway from ecosystem structure and processes to human well-being")

REFERENCES

ALLEN Bryon and LOOMIS John B. (2006), "Deriving value for the ecological support function of wildlife: an indirect valuation approach", *Ecological Economics*, N.56, pp.49-57.

AMARA Rachid (2010), « Impact de l'anthropisation sur la biodiversité et le fonctionnement des écosystèmes marins. Exemple de la Manche-mer du Nord », *VertigO*, Hors-Série 8.

ANDO Amy, CAMM Jeffrey, POLASKY Stephen, SOLOW Andrew (1998), "Species Distributions, Land Values, and Efficient Conservation", *Science*, Vol.279, No.5359, pp.2126-2128.

ANGERMEIER Paul L. and James R. KARR (1994), "Biological Integrity versus Biological Diversity as Policy Directives", *BioScience*, Vol. 44, No.10, pp. 690-697.

ARROW Kenneth J., SOLOW Robert, PORTNEY Paul R., LEAMER Edward E., RADNER Roy and SCHUMAN Howard (1993), "Report of the NOAA Panel on Contingent Valuation", 66p.

ARROW Kenneth J. and FISHER Anthony C. (1974), "Environmental preservation, uncertainty and irreversibility", *The Quarterly Journal of Economics*, pp. 312-319.

ARMSWORTH Paul R., KENDALL Bruce E. and DAVIS Frank W. (2004), "An introduction to biodiversity concepts for ecological economists", *Resource and Energy Economics*, No.26, pp.115-136.

BALMFORD Andrew, FISHER Brendan, GREEN Rhys E., NAIDOO Robin, STRASSBURG Bernardo, TURNER R. Kerry and RODRIGUES Ana S. L. (2011), « Bringing ecosystem services into the real world: an operational framework for assessing the economic consequences of losing wild nature », *Environmental Resource and Economics*, N°48, pp.161-175.

BARBIER Edward B. and Anil MARKANDYA (1990), "The conditions for achieving environmentally sustainable development", *European Economic Review*, N.34, pp.659-669.

BARRETT C. B. and GRIZZLE R. E. (1999), "A Holistic Approach to Sustainability Based on Pluralism Stewardship", *Environmental Ethics*, N. 21, pp. 23 – 42.

BARNAUD Cécile, ANTONA Martine and MARZIN Jacques (2011), « Vers une mise en débat des incertitudes associées à la notion de service écosystémique », *Vertigo*, Vol.11, N.1

BISHOP Richard C. (1978), "Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard", *American Journal of Agricultural Economics*, Vol.60, No.1, pp.10-18.

BISHOP Richard C. et Thomas A. HEBERLEIN (1979), "Measuring values of extra-market goods: are indirect measures biased?", *American Journal of Agricultural Economics*, pp.926-930.

BEAUMONT N.J., M.C. AUSTEN, S.C. MANGI and M. TOWNSENDT (2008), "Economic valuation for the conservation of marine biodiversity", *Marine Pollution Bulletin*, No.56, pp. 386-396.

BOISVERT Valérie et Frank-Dominique VIVIEN (1998), « Un prix pour la biodiversité, L'évaluation économique entre différentes légitimités », *Natures Sciences et Sociétés*, Vol.6, No.2, pp.17-26.

BRAEUER Ingo (2003), "Use of economic valuation for biodiversity conservation", *Agriculture Ecosystems and Environment*, No.98, pp.483-491.

BREKKE Kjell Arne (1997), Economic growth and the environment: on the measurement of income and welfare, Edward Elgar, Cheltenham, UK, Lyme, US.

BRITO Daniel (2005), "The importance of sound biological information and theory for ecological economics studies valuing Brazilian biodiversity: A response to Mendonca et al. (2003)", *Ecological Economics*, N.55, pp.5-10.

BROMLEY Daniel W. (2006), Sufficient reason: volitional pragmatism and the meaning of economic institutions, Princeton University Press.

BROMLEY Daniel W. (1998), "Searching for sustainability: The poverty of spontaneous order", *Ecological Economics*, N.24, pp.231–240.

BROWN Judy (2009), "Democracy, sustainability and dialogic accounting technologies: taking pluralism seriously", *Critical perspectives on accounting*, N°20, pp.313-342.

BROOKSHIRE David S., Mark A. THAYER, William D. SCHULZE, Ralph C. d'ARGE (March 1982), "Valuing Public Goods: A Comparison of Survey and Hedonic Approaches", *The American Economic Review*, Vol. 72, N°1, pp. 165-177.

BULLOCK Craig, Conor KRETSCH et Enda CANDON (2008), The Economic and Social Aspects of Biodiversity: Benefits and Costs of Biodiversity in Ireland, Government of Ireland, Dublin.

CHEVASSUS-AU-LOUIS Bernard (Rapporteur) (2009), « Approche économique de la biodiversité et des services liés aux écosystèmes : Contribution à la décision publique », CAS (Conseil d'Analyse Stratégique).

CONVENTION ON BIOLOGICAL DIVERSITY – CBD (1992).

CHAMP Patricia A., BOYLE Kevin J. et BROWN Thomas C. (2003), A primer on non-market valuation, Kluwer Academic Publishers.

COMMON Mick (2007), "Measuring national economic performance without using prices", *Ecological Economics* 4, pp. 92-102.

COSTANZA Robert, d'ARGE Ralph, De GROOT Rudolph, FARBER Stephan, GRASSO Monica, HANNON Bruce, LIMBURG Karin, NAEEM Shahid, O'NEILL Robert V., PARUELO José, RASKIN Robert G.,

SUTTON Paul, VAN DEN BELT Marjan (May 1997), "The value of the world's ecosystem services and natural capital", *Nature*, Vol. 387, p253-260.

DE GROOT Rudolf S, WILSON Matthew A., BOUMANS Roelof M.J. (2002), "A typology for the classification, description and valuation of ecosystem functions, goods and services", *Ecological Economics*, pp.393-408.

DOSI Cesare (2000), "Environmental values, valuation methods and natural disaster damage assessment", Working material, ECLAC United Nations.

DUMONT Henri J. (2005), "Biodiversity: a resource with a monetary value?", *Hydrobiologia*, No.542, pp.11-14.

EHRLICH Paul R. et Anne H. EHRLICH (1992), "The value of biodiversity", *Ambio*, Vol. 21, No. 3, pp. 219-226.

EMERTON Lucy (2005), "Counting ecosystems as part of development infrastructure: using economics valuation to promote freshwater biodiversity conservation in Africa", Symposium 2005, American Museum of Natural History and the Center for Biodiversity and Conservation, "New currents in conserving freshwater systems".

FARBER Stephen (1987), "The Value of Coastal Wetlands for Protection of Property against Hurricane Wind Damage", *Journal of environmental economics and management*, N.14, pp.143-151.

FARBER Stephen C., Robert COSTANZA et Matthew A. WILSON (2002), "Economic and ecological concepts for valuing ecosystem Services", *Ecological Economics 41*, pp.375–392.

FLEURY Cynthia and PREVOT-JULIARD Anne-Caroline (Ed.) (2012), L'exigence de la réconciliation, Ed. Fayard, 472p.

FREDERICK Shane, LOEWENSTEIN George and O'DONOGHUE Ted (2002), « Time discounting and time preference: a critical review », *Journal of Economic Literature*, Vol.XL, pp.351-401.

GARROD Guy et Kenneth G. WILLIS (1999), Economic Valuation of the Environment: Methods and Case Studies, Edward Elgard.

GODARD Olivier (2005), « Les conditions d'une gestion économique de la biodiversité -
Un parallèle avec le changement climatique », Ecole Polytechnique, CNRS, Cahier n° 2005-018.

GODARD Olivier (2004), « Autour des conflits à dimension environnementale
Évaluation économique et coordination dans un monde complexe », Ecole Polytechnique, CNRS, Cahier n° 2004-012.

GOWDY John (1997), "The value of biodiversity: markets, society, and ecosystems", *Land Economics*, Vol.73, No.1, pp.25-41.

GOWDY John (2004), "The revolution in Welfare Economics and its implications for environmental valuation and policy", *Land Economics*, Iss.80, N.2., pp.239-257.

GOWDY John (2010), Microeconomic Theory Old and New: A Student's Guide, Standford University Press.

HEAL Geoffrey (2000), « Valuing Ecosystem Services », *Ecosystems*, pp.24–30.

HEAL Geoffrey (2004), "Economics of biodiversity, an introduction", *Resource and Energy Economics* 26, pp. 105-114.

HEZRI Adnan A. and Stephen R. DOVERS (2006), "Sustainability indicators, policy and governance: issues for ecological economics", *Ecological Economics* 60, pp. 86-99.

KASSAR Ilhem and LASSERRE Pierre (2004), "Species preservation and biodiversity value: a real options approach, *Journal of Environmental Economics and Management*, N.48, pp. 857–879.

KOSOY Nicolas and CORBERA Esteve (2010), "Payments for ecosystem services as commodity fetishism", *Ecological Economics*, Vol.69, Iss.6, pp.1228–1236.

LAPP Karim (2005), « La ville, un avenir pour la biodiversité *?», Economie et Politique*, pp.51-64.

LEDOUX L. and R.K. TURNER (2002), "Valuing ocean and coastal resources: a review of practical examples and issues for further action", *Ocean & Coastal Management*, No.45, pp.583-616.

LUDWIG Donald et al. (1993), "Uncertainty, Resource Exploitation, and Conservation: Lessons from History", *Science* Vol. 260, No. 5104, pp. 17-36.

LUDWIG Donald (2000), "Limitations of economic valuation of ecosystems", *Ecosystems*, N.3, pp.31-35.

MARIS Virginie (2010), Philosophie de la biodiversité : petite éthique pour une nature en péril, Ed. Buchet-Chastel.

MARIS Virginie et Jean-Pierre REVÉRET (2009), « Les limites de l'évaluation économique de la biodiversité », *Les ateliers de l'éthique*, Vol.4, No.1, la Revue du CREUM.

MARKANDYA Anil, PERELET Renat, MASON Pamela et TAYLOR Tim (2001), Dictionary of environmental economics, Earthscan (Ed.)

MARKANDYA Anil, HAROU Patrice, BELLU Lorenzo Giovani and CISTULLI Vito (2002), Environmental economics for sustainable growth, Edward Elgar (Ed.).

McCANN Kevin S. (2007), "Protecting biostructure", *Nature*, Vol.446.

MEINARD Yves and GRILL Philippe (2011), "The economic valuation of biodiversity as an abstract good", *Ecological Economics*, Vol.70, Iss. 10, pp.1707-1714.

MENDONCA M.J.C., A. SACHSIDA, P.R.A. LOUREIRO (2003), "A study on the valuing of biodiversity: the case of three endangered species in Brazil", *Ecological Economics*, N°46, pp.9-18.

MEYERHOFF Jürgen and DEHNHARDT Alexandra (2009), "On the "non" use of environmental valuation estimates", pp.145-166, in DÖRING Ralph (Ed.)(2009), Sustainability, natural capital and nature conservation, Marburg.

NEHRING Klaus et PUPPE Clemens (2002), "A Theory of Diversity Source", *Econometrica*, Vol.70, No.3, pp.1155-1198.

NORGAARD Richard B. (2010), "Ecosystem services: From eye-opening metaphor to complexity blinder", *Ecological Economics*, N.69, pp.1219–1227.

NORTON G. Bryan (2003), Environmental ethics and weak anthropocentrism » in LIGHT Andrew and ROLSTON Holmes (Ed.) (2003), Environmental ethics: an anthology, Blackwell Publishing.

NUNES Paulo A.L.D. et Jeroen C.J.M. VAN DEN BERGH (2001), "Economic valuation of biodiversity: sense or nonsense?", *Ecological Economics*, No.39, pp. 203–222.

O'NEILL John (2003), « The varieties of intrinsic value », in LIGHT Andrew and ROLSTON Holmes (Ed.) (2003), Environmental ethics: an anthology, Blackwell Publishing.

PACE Michael L., COLE Jonathan J., CARPENTER Stephen R. and KITCHELL James F. (1999), "Trophic cascades revealed in diverse ecosystems", *Trends in Ecology & Evolution*, Vol. 14, Issue 12, pp.483-488.

PEARCE David, ATKINSON Gilles and MOURATO Susana (2006), « Cost-Benefit Analysis and the Environment: recent developments», OECD Ed., 351p.

PEARCE David and MORAN Dominic (1994), The economic value of biodiversity, IUCN-The World Conservation Union, Ed. Eathscan, 172p.

PEARCE David W. and TURNER Kerry R. (1990), Economics of natural resources and the environment, Harvester Wheatsheaf.

PEARCE David W. (2007), « Do we really care about biodiversity? », chapter 1, pp.22-54, in KONTOLEON Andreas, PASCUAL Unai and SWANSON Timothy (2007), Biodiversity Economics, University College London / or (2007), *Environmental and Resource Economics*, Vol.37, Issue 1, pp.313-333).

POTTHAST Thomas (1996), « Inventing biodiversity: genetics, evolution and environmental ethics », *Biol. Zent. Bl.*, Gustav Fischer Verlag Jena, N.115, pp.177-188.

RONNBACK Patrick et al. (2007), "Stockholm Ecosystem Goods and Services from Swedish Coastal Habitats: Identification, Valuation, and Implications of Ecosystem Shifts", *Ambio*, Vol. 36, Iss. 7, pp. 534-44.

SCBD (Secretariat of the Convention on Biological Diversity) (2010), "Global Biodiversity Outlook 3", Montréal, 94 pages.

SCHERRER Sylvie (2004), Comment évaluer les biens et services environnementaux ? *La documentation française*, Réponses environnement, 48p.

SCHROEDER Jantine, TURCANU Catrinel, VANDENHOVE Hildegarde et CARLE Benny (2009), « Environmental Valuation », SCK•CEN (Studiecentrum voor Kernenergie/Centre d'Etude de l'Energie Nucléaire), External Report, No.111.

SEN Amartya (1999), Commodities and capabilities, Oxford India Paperbacks, Oxford University Press.

SIMON Herbert A. (1997), *Administrative Behavior: A study of decision-making processes in administrative organizations*, fourth edition, the free press, 384 p.

SIMPSON David R., SEDJO Roger A. and REID John W. (1996), "Valuing biodiversity for use in pharmaceutical research", *The Journal of Political Economy*, Vol.104, N.1, pp.163-185.

SPASH Clive L. and HANLEY Nick (1995), "Methodological and Ideological Options Preferences, information and biodiversity preservation", *Ecological Economics*, 12, pp.191-208.

SPASH Clive L. (2007), "Deliberative monetary valuation (DMV) in theory", CSIRO Working paper, Series 2007-01.

TEEB (2010), The Economics of Ecosystems and Biodiversity: Ecological and Economics Foundations, Ed. Pushpam KUMAR, Earthscan, London and Washington.

THOMPSON John D. (2010), "La nature sort de sa réserve : le rôle des espaces non-protégés dans la conservation de la biodiversité", Académie des sciences, 9 février 2010, Conférence-débat "La biodiversité face aux activités humaines", heard on July 2011, 19th, http://www.academie-sciences.fr/video/v090210.htm

VATN Arild and BROMLEY Daniel W. (1994), "Choices without prices without apologies", *Journal of Environmental Economics and Management*, N.26, pp.129-148.

VARIAN Hal R. (2009), Introduction à la microéconomie, 6th Ed., Ed. De Boeck, Bruxelles.

WALLACE Ken J. (2007), "Classification of ecosystem services: problems and solutions", *Biological Conservation*, pp. 235-246.

WEBER Jacques (2003), L'évaluation contingente : les valeurs ont-elle un prix ? CERI (centre d'études et de recherches internationales), Sciences Po, Paris.

WEBER Jacques (1995), « Gestion des ressources renouvelables: fondements théoriques d'un programme de recherche ».

WEESIE Peter and Jelte VAN ANDEL (2003), "On Biodiversity and its Valuation", CDS Report Series.

WEISBROD A. Burton (1964), "Collective-consumption services of individual-consumption goods", *Quarterly Journal of Economics*, pp. 471-477.

WEITZMAN Martin L. (1992), "On diversity", *The quarterly journal of economics*, N.107, Issue 2, pp.363-405.

WEITZMAN Martin L, (1998), "The Noah's ark problem", *Econometrica*, Vol.66, N.6, pp.1270-1298.

WORM Boris, BARBIER Edward B., BEAUMONT Nicola, DUFFY Emmett, FOLKE Carl, HALPERN Benjamin S., JACKSON Jeremy B. C., LOTZE Heike K., MICHELI Fiorenza, PALUMBI Stephen R., SALA Enric Sala, SELKOE Kimberley A., STACHOWICZ John J. Stachowicz and WATSON Reg (2006), « Impacts of biodiversity loss on ocean ecosystem services », *Science*, Vol.314.

ZUINDEAU Bertrand (Ed.) (2000), Développement durable et territoires, Presses Universitaires du Septentrion.